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STUDIES ON MORTALITY IN INDIA

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Foreword

The study of mortality is of great interest to public health workers and demographers throughout the world. Not only health planning but planning for improvement of socio-economic condition depends to a great extent on current data on mortality and its future trends. A remarkable event in history has been the spectacular decline in death rate both in the developed and the developing nations. While the fall in death rates in the present day developed world has been gradual and has been the result of combined efforts in improvement of socio-economic conditions, sanitation and medical know-how, the current rapid decline in mortality in the developing nations is attributable greatly to the application of principles of scientific medicine to disease control.

It is being argued whether the recent rapid decline in mortality in the developing nations can be continued into the future. Many feel that the easily conquerable diseases have been controlled and future decline in mortality will be conditional to the concurrent improvement in the fields of malnutrition, poverty, illiteracy and medical care.

Irrespective of the speed of decline of mortality in the future, most of the developing nations are likely to invest huge sums for improvement of the health of the citizens. Improvement of public health is one of the directive principles of State policy in India. Every nation is trying to achieve for its citizen the maximum state of physical and mental health within its economic capability. The tasks in the future will be not only to consolidate the gains achieved so far in reduction in mortality but to improve upon it. The Second Development Decade will facilitate this process a great deal.

While a great deal is known about an overall decline in mortality, there is still inadequate information on mortality differentials in various age and socio-economic groups and between sexes; causes of mortality; relationship of mortality to fertility; measurement of mortality; and future trends in mortality.

The major objective of the Gandhigram Institute of Rural Health and Family Planning is to contribute towards the promotion of health and family planning programme in the country and this is being achieved through the three inter-related activities of training, research and field service demonstration. It is this deep involvement of the Institute in the field of community health with priority to family planning that has encouraged us to bring forth the present monograph, pooling together the findings of studies on mortality in different parts of the country. It is hoped that the monograph will help to bring to the readers knowledge on the current status of mortality in the country, identify gaps in knowledge, and stimulate further studies on the subject.

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Dr. K. A. Pisharoti
Director

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A word of appreciation is due to Mr. P.K. Thyagarajan, our editor, and other staff members of the Institute who have taken special care to see the monograph through the press.

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Contents

Foreword (i)

Contributors to this Monograph (iv)

MEASUREMENT OF MORTALITY

1. Testing Deficiencies in Death Registration Statistics and Estimation of Mortality in India — *K. E. Vaidyanathan*

2. Infant Death Rates in Poona City: An Evaluation — *K. Dandekar and Vaijayanti Bhate*

3. Measures of Mortality from Indian Sample Registration System — *V. K. Ramabhadran and V. S. Swamy*

4. Measurement of Mortality in Rural Gujarat Under Sample Registration — *D. C. Mehta and M. H. Shah*

5. The OSR Method of Estimating Mortality Levels — *K. V. Ramachandran and P. S. G. Nair*

6. Estimation of Mortality from a single age Distribution of Population — *M. L. Srivastava*

7. Some Indices of Differential Mortality — *K. E. Vaidyanathan*

8. On Ascertaining Causes of Death in Rural India — *V. K. Ramabhadran and Brijesh B. Lal*

ANALYTICAL MORTALITY STUDIES

9. Mortality and Longevity in India, 1901-61 — *K. Dandekar*

10. Infant Mortality in an Urban Setting: The Case of Greater Bombay — *L. T. Ruzicka and T. Kanitkar*

11. Analysis of Factors Affecting Infant and Early Childhood Mortality — *P. S. S. Sundar Rao*

12. Current Research on Morbidity and Mortality in the ICMR
— *A. D. Taskar and Shantha Madhavan*

13. Public Health Aspects of Mortality Trends and Levels
— *Alwyn Smith*

IMPACT OF CHANGES IN MORTALITY

14. Impact of Prevention of Selected Causes of Death on Life Expectancy — *G. Ramakrishna and M. V. Raman*

15. Effect of Changing Mortality and Fertility on the Population of Kerala — *R. Ramakumar*

16. Mortality in India in Relation to Prospects of Fertility Decline
— *S. Krishnaswamy Rao, P. S. Mohapatra* and *P. S. Bhatia*

17. Effect of Declining Mortality on Fertility — *R. S. S. Sarma*

18. Effect of Declining Mortality on the Incidence of Widowhood
— *R. S. S. Sarma*

19. Impact of Variations in Mortality on the Length of Working Life — *U. P. Sinha*

LIFE TABLES AND PROJECTIONS

20. The Scope and Limitations of Model Life Tables
— *V. G. Valaoras*

21. An Approach to the Revision of Model Life Tables
— *R. S. Kurup*

22. Graduation of Life Table Functions — *S. Mitra*

23. Mortality Projections for India upto 1985
— *K. S. Gnanasekaran*

24. A Hypothetical Indian Population Projection
— *G. E. Immerwahr*

Measurement of Mortality

Testing Deficiencies in the Death Registration Statistics and Estimation of Mortality in India, 1965—1966

K. E. Vaidyanathan *

Introduction

In countries with defective registration statistics, estimation of demographic measures have necessarily to depend upon the available data from vital registration, censuses and surveys supplemented by international experience. India has a long history of vital registration, yet the registration statistics are deficient in many respects. In this paper, it is proposed to examine the available death registration statistics for the year 1965 and 1966, to bring out deficiencies in the data and to utilize them for deriving estimates of mortality in India during 1965-66 which corresponds with the middle of the 1961-1971 decade.

The data used in this study are for the 13 major states and two Union Territories of India covering 80 per cent of the population of the country [1]. This limitation was necessary to avoid changes in registration coverage, and also because registration in the rest of India is so poor to merit inclusion. The important source of data for the present study is the annual publication of the Registrar General of India known as the *Vital Statistics of India*. The figures used here are drawn from the above publication for 1965 and 1966. In addition an estimate of the growth rate during 1961-1971, from the provisional results of the 1971 census has also been utilized in this study.

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The evaluations that are attempted in this study are necessarily restricted by the classifications of the data available in these publications. Deaths have been classified by sex and broad age groups, namely 0, 1-4, 5–9, 10-14, 15-19, 20–29, 30–39, 40-49, 50-59 and 60 and over; further, infant deaths are tabulated separately for less than one week, one week to one month, one month to six months and six months and over. More detailed five-year age groupings at the adult ages or a grouping like 25-34, 35-44, ... with ages ending in the digit zero at the middle should have been preferred to the present age grouping. Also the terminal age group should be higher (preferably 80+) instead of the present 60 and over, especially since more people may be expected to live beyond 60 with rising expectancies of life. For infant deaths we would have preferred tabulations by age intervals of one month to the present irregular age groups. Further the age tabulation of deaths for the major cities of India, or for other areas of reportedly good registration are not available. Despite these limitations in the available classifications, the data are of great value for estimation of mortality in India.

Areas of Deficiency in Mortality Statistics

Three broad areas of deficiency can be noticed in the death registration statistics of statistically under-developed countries [2]:

a. Incomplete registration of infants who die immediately after birth ;

b. Unconventional sex differentials in mortality, especially during infancy and early childhood ;

c. Distortion of age patterns of deaths due to differential registration and misstatements of age.

Incomplete registration of early infant deaths is more acute in the rural areas of the country (localities of less than 5000 inhabitants). This can be seen from a comparison of the age-sex characteristics of infant deaths in rural areas, urban areas and selected major cities (average for 1965 and 1966) presented in Table 1.

Table 1

AGE AND SEX CHARACTERISTICS OF INFANT DEATHS IN RURAL AREAS, URBAN AREAS AND MAJOR CITIES OF INDIA BASED ON REGISTRATION OF DEATHS DURING 1965 - 1966

Age at death	Per cent deaths by age at death						Per cent of males to all deaths		
	Rural		Urban		Major cities*		Rural	Urban	Major cities*
	M	F	M	F	M	F			
Under 1 week	13.2	10.2	17.6	13.4	20.0	14.3	56.4	56.7	58.3
1 week- 1 month	10.3	8.2	9.4	7.8	11.4	9.8	55.6	54.6	53.8
1 month- 6 months	13.8	12.1	13.7	12.6	12.5	11.6	53.2	52.0	51.7
6 months- 1 year	16.7	15.2	12.6	12.7	9.8	10.4	47.6	49.8	48.5
Under 1 year	54.1	45.8	53.3	46.6	53.7	46.2	54.1	53.3	53.8
	Infant Death Rate						Sex Ratio in Death Rate		
Under 1 week	18.1	15.8	20.4	16.3	34.0		115	125	N A
1 week- 1 month	14.0	12.7	10.9	9.5	21.0		111	114	N A
1 month- 6 months	18.8	18.7	15.9	15.4	23.9		100	103	N A
6 months- 1 year	22.8	23.4	14.6	15.5	20.0		97	94	N A
Under 1 year	73.8	70.8	61.9	56.8	98.9		104	109	N A

* The cities included are Bombay, Calcutta and Nagpur only as the information is not available for other cities.

Source: Computed from *Vital Statistics of India*, 1965 and 1966 published by the Registrar General, India (Released in 1970 and 1971 respectively)

During 1965-1966 there were in round numbers 394,000 infant deaths among 5,435,000 livebirths in rural areas, as against 130,000 infant deaths among 2,200,000 livebirths in urban areas. The infant death rate was 72.3 in rural areas as against 63.4 in urban areas, or 14 per cent higher. On the other hand, the death rate for the first week is lower for rural areas than for urban areas, which is clearly unacceptable. Also one should expect on the basis of international experience that the proportion of infant deaths occurring during the first week of life should be nearly one-third, whereas it is less than one-fourth in rural areas. It is apparent that there is considerable omission of the deaths occurring during the first week of life.

That the failure to register is not confined to the first week of life or to rural areas alone is evident when we compare the rates for rural and urban areas with those for the selected major cities. Generally health conditions in the major cities are better than those in rural areas as well as in urban areas as a whole, because of such factors as availability of medical facilities, protected water supply better living conditions and the like. Therefore one should expect to find the death rate for rural areas and urban areas to exceed those for the major cities. The opposite tendency of a lower death rate for these areas compared to the rate for major cities is clearly an artefact of the serious deficiencies in the data. Again, a comparison of the proportion of male deaths to total deaths for rural and urban areas with those for major cities does not indicate any differential omission of infant deaths of a particular sex.

Several surveys of underregistration of births and deaths have been undertaken in different parts of India by the Office of the Registrar General of India. These surveys indicate that the underregistration of births and deaths is of a very high order [3]. It is very likely that some of the infant deaths were not registered both as infant death as well as livebirth. It would have been useful if the proportion of such cases had been ascertained in the surveys of underregistration. Unfortunately, this is not available. If for the sake of illustration it is assumed that ten per cent of livebirths have escaped registration as livebirth and as infant death, the infant mortality rate for rural areas will be increased to 160 from the present level of 72. This is purely conjectural and we need further

evaluation before we can arrive at a firm estimate of infant mortality rate.

In order to obtain an idea of the likely range of underregistration of infant deaths, one may start with the estimate of the birth rate, about which there is a greater degree of consistency in the Indian demographic literature. This is because, unlike in the case of deaths, the survivors of the new born aged 0-4 and 5-9 can be observed in censuses and surveys and retrospectively one is able to estimate the number of births, of which they are the survivors. There is considerable amount of agreement between the estimates of birth rates obtained by different scholars and by different methods and in the absence of a significant change in fertility in the past, there is also near stability in the estimated birth rates for the recent past. These studies indicate a birth rate of nearabout 40 for India [4].

For the purpose of a simple exercise on the likely magnitudes of underregistration of infant deaths, one may therefore assume a birth rate of 40 for rural areas and 35 for urban areas. These rates on multiplication by the average midyear population for 1965—1966 result in an estimate of the number of livebirths in rural and urban areas. (See Table 2). The total number of livebirths thus obtained are then split into the number of male and female livebirths on the assumption of a masculinity ratio of 0.51 for both rural and urban India which corresponds to a sex ratio of 106 male births to 100 female births [5]. It was noted in the earlier section that for the few major cities for which data are available, the infant mortality rate was 98.9 in 1965—66. One should expect the infant mortality rate for rural and urban areas to be higher than this figure. In the absence of firm estimates of infant mortality rates for rural and urban areas, one may assume that it is in the range of 130 and 160 for rural areas and between 100 and 130 for urban areas. On the basis of this assumption, the number of infant deaths in rural India will range between 1,435,000 and 1,767,000, as against the reported figure of 399,000 infant deaths. (See Table 2). Likewise, in urban India, the number of infant deaths in 1965—66 will range between 245,000 and 320,000 infant deaths as against a reported number of 131,000 infant deaths. This exercise would indicate that only between 23 and 28 per cents of infant deaths in rural areas are registered

whereas the extent of registration completeness ranges between 45 and 60 per cents in urban areas. An interesting conclusion from this exercise is that the degree of underregistration of infant deaths is only slightly greater for females.

Table 2

ESTIMATION OF THE LIKELY UNDERREGISTRATION OF INFANT DEATHS IN RURAL AND URBAN INDIA, 1965 - 1966

		Rural		Urban	
		Males	Females	Males	Females
		(Figure in thousands)			
1.	Estimated No. of Livebirths	5,630	5,410	1,250	1,200
2.	Reported No. of Livebirths	2,900	2,630	1,130	1,030
3.	Underregistration of Livebirths	2,730	2,780	120	170
4.	Estimate of No. of Infant Deaths				
	a. at IDR of 130 for rural and 100 for urban	732	703	125	120
	b. at IDR of 160 for rural and 130 for urban	901	866	163	156
5.	Reported No. of Infant Deaths	216	183	70	61
6.	Underregistration of Infant Deaths				
	a. Minimum Estimate	516	521	53	59
	b. Maximum Estimate	685	683	93	45
7.	Percent of underregistration [(6) ÷ (4)] × 100				
	a. Minimum Estimate	70.4	74.1	42.4	49.2
	b. Maximum Estimate	76.0	78.8	57.1	60.9

Source : Computed on the assumption of a birth rate of 40 per 1000 forrural areas and 35 per 1000 for urban areas. The estimated population for 1965-66 used in the calculations are the following in thousands. Rural: 276,023; Urban: 69,705.

The failure to register is serious in the case of infant deaths especially those who die shortly after birth, but such omissions are not uncommon in the remaining age segments of the population. Even in the case of urban areas there is considerable amount of underregistration, especially in the so-called " census towns ", which seem to suffer from the fact that often a single registrar of births and deaths has to cover a large area, and reciprocally, the distance travelled by a person who wants to report a vital event is also greater[6]. One may assume as a kind of "rule of thumb", that the percentage under registration of deaths at ages one and over is between one half and two-third of the percentage underregistration of infant deaths[7]. On this basis, one can estimate the range of omission of all deaths in rural and urban India, by aggregating the estimates of omissions in infant deaths and of deaths at ages one and over. (See Table 3). It may be seen from the table that the estimated underregistration of the deaths at all ages ranges between 50 and 62 per cents in rural India and between 25 and 43 per cents in urban India. Once again it is noticed that the underregistration of the two sexes are very much of the same order, it being only slightly more for females. The estimated crude death rate ranges between 17.3 and 20.9 in rural India and between 13.7 and 17.0 in urban India. In order to determine the probable value of the infant mortality and crude death rates, further analysis of the data is needed, especially the determination of the overall levels of mortality.

The third kind of deficiency in the death registration statistics is the distortion of the age patterns of mortality arising from two factors, namely the differential omissions in different age segments and wholesale transfer of persons across the age boundaries due to misstatement of age. These two sources of errors are compounded together in the recorded distribution of deaths by age. When the age-sex specific death rates are worked out, an additional factor is introduced, namely the inaccuracies in the age distribution of the population in the denominator of the rates. In Table 4, the age-specific death rates and the percentage distribution of deaths by age for each sex for rural and urban areas of India are presented. Since the reported crude death rates are not much different for the two areas, one should expect the age pyramids of deaths for the two areas to nearly coincide with each other. An examination of the above table indicates relatively larger omission of infant deaths relative to total

Table 3

ESTIMATION OF THE RANGE OF UNDERREGISTRATION OF DEATHS OF ALL AGES IN RURAL AND URBAN INDIA, 1965-1966

	Rural		Urban	
	Males	Females	Males	Females
1. Estimated number of infant deaths (Item 4 of table 2)				
a. Minimum Estimate (000)	732	704	125	120
b. Maximum Estimate (000)	901	866	163	156
2. Reported No. of deaths at age one and over (000)	980	885	296	246
3. Correction factors for deaths at ages one and over				
a. Minimum Estimate	1.7	1.9	1.3	1.3
b. Maximum Estimate	2.1	2.2	1.6	1.6
4. Estimated No. of deaths at ages one and over				
a. Minimum Estimate (000)	1,666	1,682	385	320
b. Maximum Estimate (000)	2,058	1,947	474	314
5. Estimated No. of deaths of all ages (1) + (4)				
a. Minimum Estimate (000)	2,398	2,386	510	440
b. Maximum Estimate (000)	2,959	2,813	637	550
6. Reported No of deaths of all ages (000)	1,196	1,067	366	307
7. Estimated underregistration of deaths of all ages				
a. Minimum Estimate (000)	1,202	1,319	144	133
b. Maximum Estimate (000)	1,763	1,746	271	243
8. Per cent underregistration [(7) ÷ (5)] × 100				
a. Minimum Estimate	50.1	55.2	28.2	30.2
b. Maximum Estimate	59.5	62.0	42.5	44.2

Table 4

REPORTED AGE SPECIFIC DEATH RATES AND PERCENTAGE OF DEATHS BY AGE FOR RURAL AND URBAN INDIA, 1965-1966

Age Group	Age Specific Death Rate				Percentage of deaths by age			
	Rural		Urban		Rural		Urban	
	Males	Females	Males	Females	Males	Females	Males	Females
0	49.61	42.03	69.93	63.50	18.03	17.11	19.18	19.98
1-4	12.00	11.98	12.29	13.14	16.95	18.88	12.94	15.95
5-9	3.07	2.91	3.02	2.92	5.41	5.50	4.10	4.44
10-14	2.14	2.18	2.26	2.25	2.95	2.95	2.63	2.73
15-19	2.95	2.98	2.61	3.39	2.78	3.01	2.46	3.11
20-29	2.48	2.72	2.87	4.00	4.55	5.95	5.62	7.74
30-39	3.73	3.90	4.35	5.31	5.61	6.21	6.46	6.99
40-49	6.49	5.51	8.21	6.92	7.32	6.37	8.38	6.02
50-59	12.73	10.58	17.64	12.14	9.72	8.06	10.70	6.72
60+	39.72	34.37	60.37	49.56	26.68	25.96	27.53	26.32
All ages	8.50	7.88	9.70	9.63	100.00	100.00	100.00	100.00

Source: Computed using death registration statistics and estimated mid year population from Registrar General, India, *Vital Statistics of India,* 1965 and 1966 and unsmoothed age distribution of 1961 census taken from United Nations *Demographic Yearbook.*

deaths in rural areas and a greater distortion of the age distribution of male deaths. It also appears that the proportion of deaths in the broad range of ages 10-20 is probably nearer to reality than those in any other age group. These observations are confirmed by the comparison of the estimated levels of mortality in stable populations that correspond closely to the reported age-sex specific death rates (${}_nm_x$) and the proportions of deaths (d_x) by age[8]. (See Table 5). It may be seen that the estimated "mortality levels" for rural areas are generally higher than those obtained for urban areas, which is clearly impossible since the health conditions in rural areas are poorer than those in urban areas. The range of variation in the estimated levels is also greater for rural areas, and there are wide fluctuations in mortality levels from one age group to the next. Thirdly, the proportions of deaths in rural areas in 5-9, 10-14 and 40-49 age groups for both

Age Specific Death Rates | Percentage of Deaths by Age

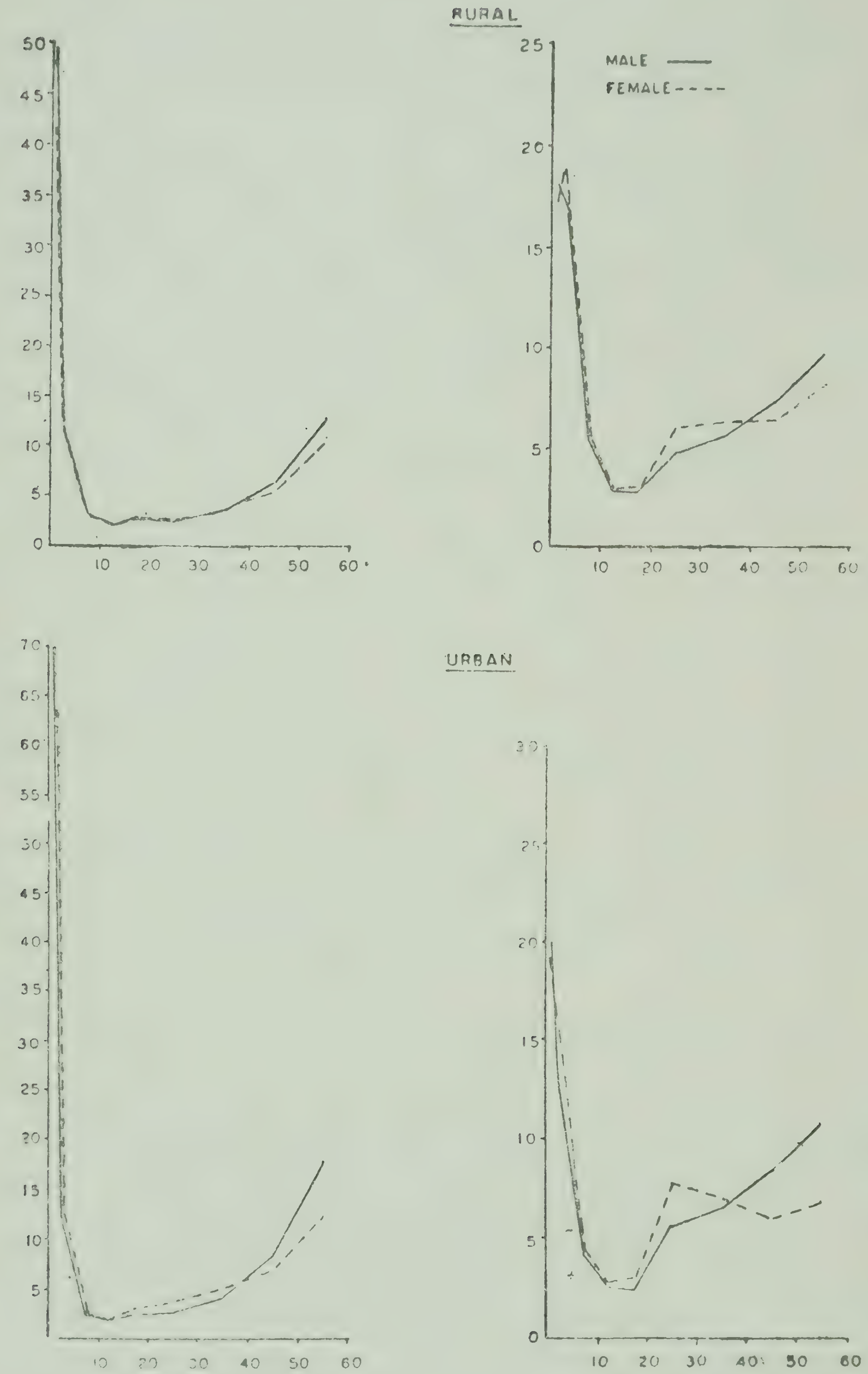

Fig. 1 : *Reported age specific death rates and proportions of deaths by age for each sex for rural and urban India, 1965-66*

Table 5

ESTIMATED MORTALITY LEVELS FOR RURAL AND URBAN INDIA BY SEX BASED ON THE REPORTED ${}_{n}m_x$ AND d_x.

Age Group	Based on ${}_{n}m_x$				Based on d_x			
	Rural		Urban		Rural		Urban	
	Males	Females	Males	Females	Males	Females	Males	Females
0	20.4	20.0	18.7	17.9	19.9	19.2	19.4	17.8
1-4	15.6	15.4	15.4	14.5	8.1	7.3	15.0	11.2
5-9	15.3	15.5	15.4	15.5	—	—	—	—
10-14	15.7	15.7	15.3	15.5	—	—	—	2.7
15-19	16.6	16.0	17.8	15.2	—	11.6	15.4	10.0
20-29	19.9	18.5	19.2	16.4	19.6	15.5	16.8	—
30-39	19.2	18.2	18.3	16.3	16.8	11.5	—	—
40-49	19.5	18.8	17.7	17.0	—	—	—	15.0
50-59	21.4	19.1	22.1	17.7	17.2	16.7	20.1	12.7
60+	—	—	—	23.7	15.2	13.8	15.4	13.9
Median Level*	15.7	15.7	15.4	15.5	—	—	—	—

Source: Computed using the ${}_{n}m_x$ and d_x values shown in Table 4 and Coale-Demeny West Models.

* Median Levels are based on the first five values only.

males and females and for the 15-19 age group for males would imply mortality levels outside the range covered by the Coale-Demeny West Models, which is unacceptable. A similar aberration can be noticed for urban areas also in the 5-9, 10-14, 30-39 and 40-49 age groups for males and the 5-9, 20-29 and 30-39 age groups for females. This analysis confirms our earlier observation that the age reporting of death is less accurate in rural areas than in urban areas, and also it is more distorted for males than for females in both areas. It may be noticed that the age-specific death rates for the two areas are less distorted than the proportions of deaths by age, probably because of a possible cancellation of similar kind of errors in the distributions of deaths and of population. However in view of fluctuations in mortality levels the age specific death rates do not provide an adequate basis for estimating the mortality levels in India. An examination of the cumulative proportions is attempted in the next section to determine the level of mortality in India.

Selecting a Mortality Level on the Basis of the Cumulative Proportions of Deaths by Age Groups

Parameters of an actual population can be estimated by locating the model stable population that fits certain recorded or calculated features of the population in question, and then assigning the characteristics of the model stable to the actual population. Informations of the actual population that can be utilized are the distribution of population by age groups, or the sex-age specific death rates, or the percentage distribution of deaths by age groups, together with the average rate of natural increase, which can be computed by suitably adjusting the intercensual rate of growth for possible references in coverage, and gain or loss through migration. At the time of writing this paper the sex-age distribution of the population from the 1971 census has not become available, and as noted in the last section the age specific death rates and the recorded proportions of deaths by age are too distorted to give any meaningful picture of mortality levels. The problem of estimating the mortality levels in India then becomes one of finding a stable population with a given annual rate of increase that most closely reproduces the recorded cumulative age proportion of deaths.

The reason for the choice of the cumulative proportions of deaths as the basis is obvious. The effects of age misreporting and differential omission in different age groups is less on the cumulative deaths than in particular age brackets, (See Table 6 and Figure 2). The proportion of deaths under age x, which may be designated as D_x is affected by those misstatements which involve a net transfer of persons across age x. A stable population can then be identified by the intercensual rate of increase and any specified cumulative proportion, say upto age 5, upto age 10, ... upto age 60. If the reported population in fact has a stable form, if the age reporting is accurate, and if there are no differential underregistration by age, the series of stable populations identified with D (5), D (10), ... D (60) will resemble each other. Deviations from conditions of stability in the recent past, as well as errors in the data would lead to a spreading out of the levels of mortality consistent with the cumulative proportions upto different ages.

In the case of India it can be assumed that approximately stable conditions exist (as there are no visible declines in fertility and

besides mortality declines have only second order effects), and further the intercensual rate of growth based on the censuses of 1961 and 1971 will approximate the rate of natural increase during 1965–1966. It can also be assumed that the rate of natural increase for rural and urban areas are nearly the same [9]. The mortality levels consistent with D(5), (D10), ... D(60) and the rate of natural increase of 22 per thousand are obtained by interpolation from the Coale-Demeny Model Life Tables.

Table 6

CUMULATIVE PERCENTAGES OF DEATHS UPTO AGE X (D_x) FOR RURAL AND URBAN INDIA, 1965 - 1966

Age	Rural		Urban		Rural		Urban	
X	Males	Females	Males	Females	Males	Females	Males	Females
	A : Beginning at age Zero				B : Beginning at age 5			
1	18.03	17.11	19.18	19.98	—	—	—	—
4	34.98	35.99	32.12	35.93	—	—	—	—
9	40.39	41.49	36.22	40.37	8.32	8.59	9.92	11.19
14	43.34	44.44	38.85	43.10	12.86	13.19	9.92	11.19
19	46.12	47.43	41.31	46.21	17.14	17.90	13.54	16.05
29	50.67	53.40	46.93	53.95	24.15	27.19	21.83	28.12
39	56.28	59.61	53.39	60.94	32.77	36.90	31.35	38.03
49	63.60	65.98	61.77	66.96	44.03	46.85	43.69	48.42
59	73.32	74.04	72.47	73.68	58.98	59.44	59.45	58.91
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source : Computed from Table 4.

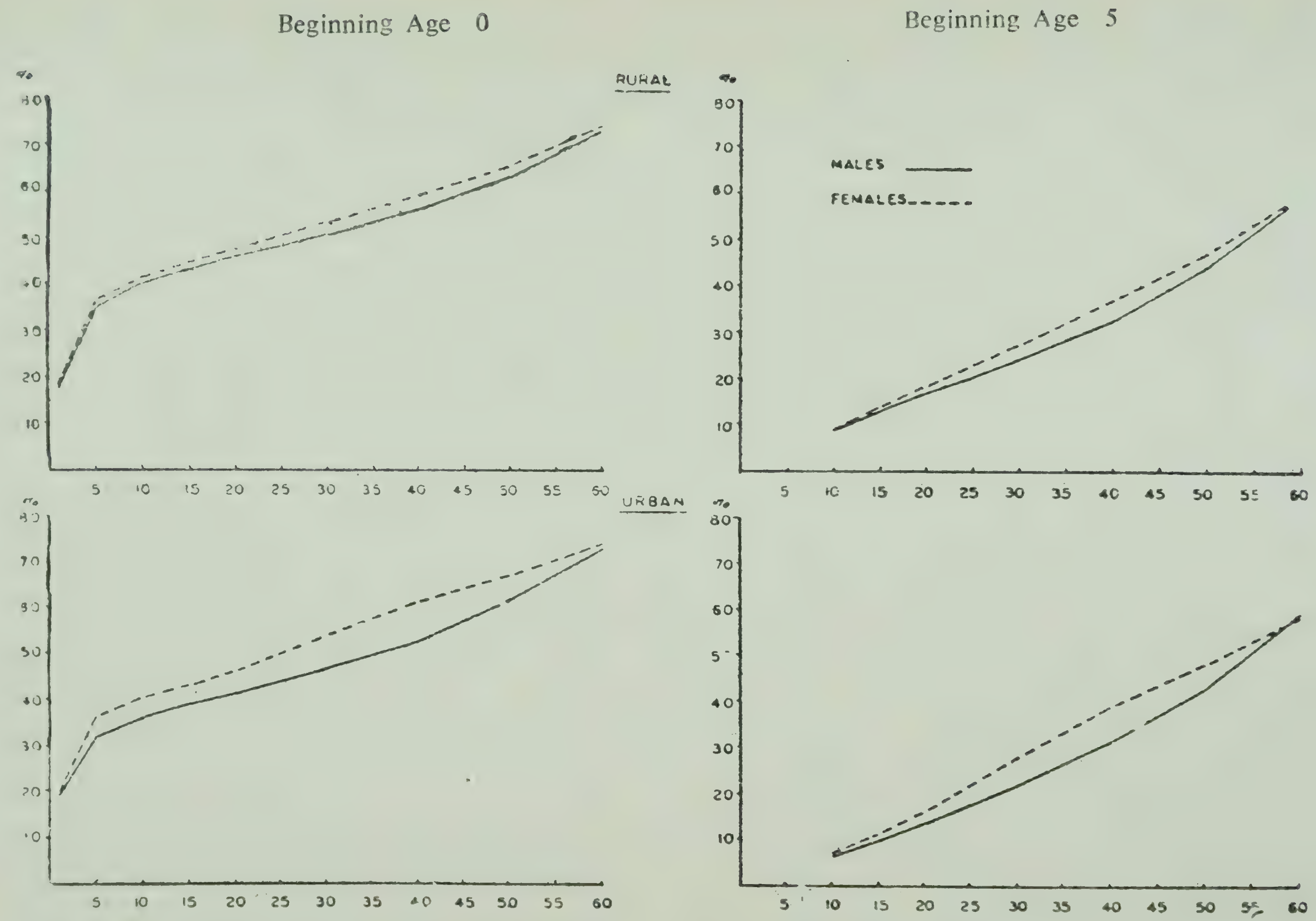

Fig. 2 : *OGIVE of the age distribution of deaths for rural and urban India, 1965-66*

The estimated mortality levels based on the cumulative proportion of deaths and the rate of growth of 22 per thousand are shown in Table 7. In the A segment of the Table, the cumulative proportions are worked out beginning from the age 0, which corresponds to the age groups 0–4, 0–9, 0–15 etc. In the B segment of the Table the cumulative proportions are worked out beginning from age 5, and corresponds to the age groups 5–9, 5–14, 5–19 and so on. The computation of the levels of mortality associated with the cumulative death proportions beginning from age 0 is straightforward, as the figures can be read off or interpolated directly from the Coale-Demeny Tables. The computation of the levels associated with the proportion of deaths in the cumulative ages beginning from age 5 (B segment of Table 7) is however time consuming. One has to first convert the proportion of deaths at different levels of mortality and at different rates of growth given in the Coale-Demeny Table into the "new" stable death proportions beginning from age 5. These figures are then utilized for reading off or for interpolating the mortality levels associated with the cumulative death proportions shown in the lower segment of Table 6, and the assumed rate of growth.

The results obtained are interesting. It is noticed that the estimated mortality levels in the A segment vary from 15.0 to 19.9 for males and from 13.8 to 19.2 for females in rural areas. In the case of urban areas the range is between 15.4 and 19.4 for males and between 13.8 and 17.8 for females. In either case the highest value relates to the age group 0-5 arising on account of the underregistration of infant and early childhood deaths. The median levels for males and females are 15.4 and 14.4 respectively in rural areas and 16.7 for males and 14.7 for females in urban areas. These estimates are likely to be overestimated on account of the trough in the 0-4 age group, and the consequent understatement of the subsequent cumulative proportions.

The cumulative proportions beginning from age 5 avoid the influence of the underregistration of infant deaths and therefore the median mortality levels obtained by this procedure are smaller, namely, 10.5 for males and 11.2 for females in rural areas and 13.5 for males and 12.2 for females in urban areas. The true levels of mortality are likely to fall between the two sets of values specified by the A and B segments of Table 7. In the situation prevalent in India,

Derived from cumulative death proportions beginning age 0

Derived from cumulative proportions beginning age 5

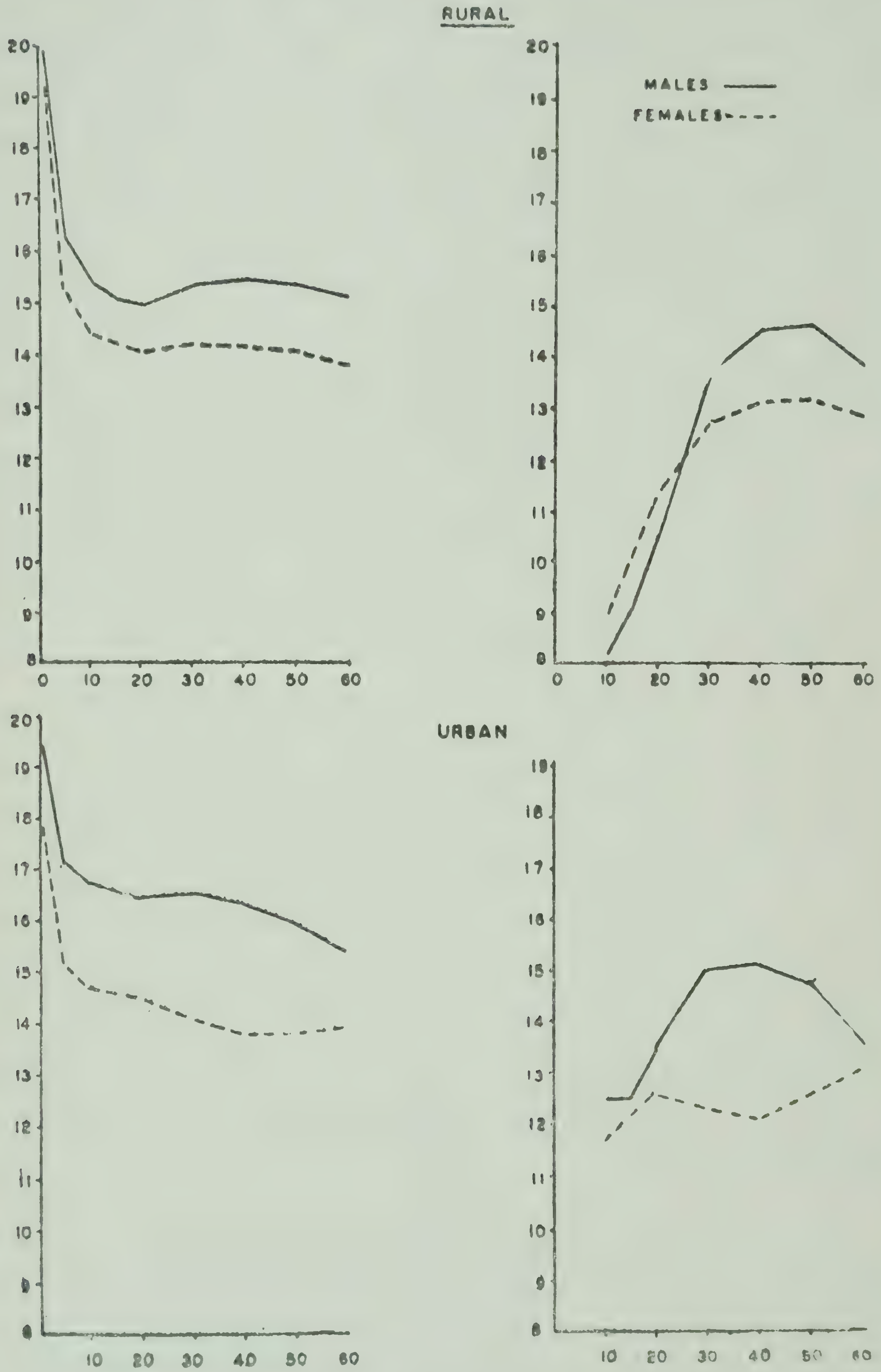

Fig. 3 : *Mortality levels estimated from cumulative death proportions for rural and urban India, 1965-66*

Table 7

ESTIMATES OF MORTALITY LEVELS BASED ON CUMULATIVE DEATH PROPORTIONS (D_x) FOR RURAL AND URBAN INDIA, 1965 - 1966

Age X	Rural Males	Rural Females	Urban Males	Urban Females	Rural Males	Rural Females	Urban Males	Urban Females
	A : Beginning at age Zero				B : Beginning at age 5			
1	19.9	19.2	19.4	17.8	—	—	—	—
4	16.3	15.3	17.2	15.2	—	—	—	—
9	15.4	14.4	16.7	14.7	8.2	8.9	12.5	11.7
14	15.1	14.2	16.5	14.6	9.0	10.1	12.5	12.2
19	15.0	14.1	16.4	14.5	10.5	11.2	13.5	12.6
29	15.4	14.2	16.5	14.1	13.7	12.7	15.0	12.3
39	15.5	14.2	16.3	13.8	14.5	13.1	15.1	12.1
49	15.4	14.1	15.9	13.8	14.6	13.1	14.7	12.6
59	15.2	13.8	15.4	13.9	13.8	12.8	13.6	13.1
Median Level*	15.4	14.4	16.7	14.7	10.5	11.2	13.5	12.2

* Median Levels based on first five values only.

Source : Computed using D_x values shown in Table 6 and Coale-Demeny West Models.

the life expectancy of males are higher than that of females, and secondly, the life expectancy in urban areas is likely to be higher than in rural areas. On these considerations, one may accept the levels of 13.0 for males 11.5 for females in rural areas and 14.0 and 12.5 for males and females respectively in urban areas. The All India Mortality levels obtained as a weighted average of the rural and urban mortality levels are 13.2 and 11.7 for males and females respectively. These yield expectations of life at birth of 47.1 for males and 46.3 for females in rural areas and 49.6 for males and 48.8 for females in urban areas. The estimated expectations of life at birth for All-India in 1965-1966 are 47.6 for males and 46.8 for females and the expectations of life at age 5 amount to 54.0 for males and 53.9 for females. These estimates seem to be realistic in the Indian context as shown by the analysis in the subsequent sections.

Rectification of the Number of Deaths

As a final outcome of this exercise, one could now rectify the errors in the data and compare the rectified death statistics with the

reported data. This is done by reading off from the Coale-Demeny West Models the infant mortality rates by sex and the age-sex specific death rates for rural and urban India corresponding to the levels of mortality estimated in the previous section, namely, 13.0 and 11.5 for males and females respectively in rural areas and 14.0 and 12.5 for males and females respectively in urban areas. These are shown in Table 8 along with the reported rates. (Also see Figure 4) It may be noticed that the discrepancy between the estimated and reported rates are at their maximum for infants, which is followed by a steep decline in the subsequent age groups and reach the lowest in the 5-9 age group. There after it rises gradually and reaches a secondary peak in 20-29 and declines again. This pattern is observed in both rural and urban areas, but the discrepancy is greater in rural areas.

Table 8

ESTIMATED AND REPORTED DEATH RATES BY AGE AND SEX, RURAL AND URBAN INDIA, 1965 - 1966

Age Group	RURAL				URBAN			
	Males		Females		Males		Females	
	Estimated	Reported	Estimated	Reported	Estimated	Reported	Estimated	Reported
Under one year*	139.42	73.88	138.92	70.80	124.53	61.95	125.01	56.87
1-4	18.58	12.00	23.41	11.98	15.64	12.29	20.33	13.14
5-9	4.16	3.07	5.20	2.91	3.65	3.02	4.61	2.92
10-14	3.01	2.14	4.05	2.18	2.66	2.26	3.58	2.25
15-19	4.43	2.95	5.45	2.98	3.97	2.61	4.86	3.39
20-29	6.63	2.48	7.39	2.72	5.92	2.87	6.62	4.00
30-39	8.73	3.73	9.38	3.90	7.78	4.35	8.56	5.31
40-49	13.26	6.49	11.79	5.51	12.07	8.21	10.76	6.92
50-59	23.01	12.73	19.45	10.58	21.58	17.64	18.02	12.14
60+	74.81	39.72	70.82	34.37	73.23	60.37	68.27	49.56
All ages	18.17	8.50	18.85	7.88	15.23	9.70	16.12	9.63

* Infant Mortality Rate

Source : The estimated rates are derived from Coale-Demeny West Models corresponding to levels 13.0 and 11.5 for males and females respectively in rural areas and levels 14.0 and 12.5 respectively for males and females in urban areas. The reported figures are from Table 4.

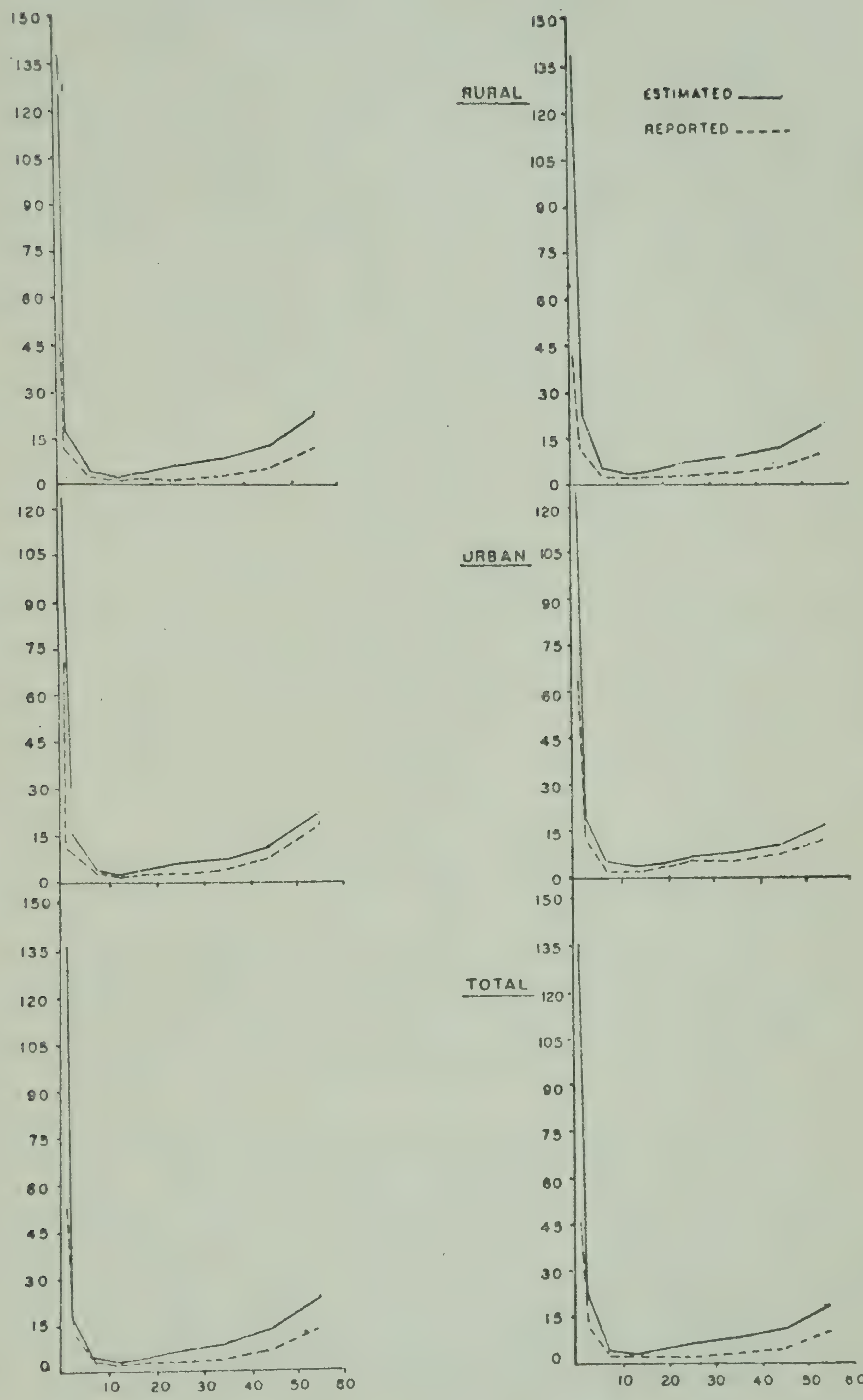

Fig. 4 : *Estimated and reported age-sex specific death rates for rural and urban India 1965-66*

Table 9

REPORTED AND CORRECTED NUMBERS OF DEATHS BY BROAD AGE GROUPS 1965 - 1966

Age Group	RURAL Reported No.	RURAL Estimated No.	RURAL Difference	RURAL Diff./Est. %	URBAN Reported No.	URBAN Estimated No.	URBAN Difference	URBAN Diff./Est. %
Males								
0	215605	784935	569330	72.53	70284	155663	85379	54.85
1–19	335880	500825	164945	32.93	81100	103520	22420	21.66
20–49	209017	481310	272293	56.57	74974	129917	54943	42.29
50 +	435027	810587	375560	46.33	140006	170245	30239	17.76
All Ages	1195529	2577657	1382128	53.62	366364	559345	192981	34.50
Females								
0	182689	751449	568760	75.69	61403	150012	88609	59.07
1–19	323841	606089	282248	46.57	80614	124932	44318	35.47
20–49	197752	477236	279484	58.56	63752	102729	38977	37.94
50 +	363083	729096	366013	50.20	101526	142069	40543	28.54
All Ages	1067365	2563870	1496505	58.37	307295	519742	212447	40.88

Source : The estimated values are derived by applying the ${}_1q_0$ and ${}_nm_x$ values to the estimated numbers of livebirths and population by age groups.

The number of deaths in age-sex group in the two areas are estimated by multiplying the estimated population in each age-sex group by the corresponding estimated $_nm_x$ values. The number of infant deaths are estimated by applying the estimated infant mortality rates to the estimated number of livebirths by sex and rural-urban residence. (See Table 9). The crude death rates are estimated by aggregating the estimated numbers of deaths in the different age groups and expressing them in relation to the estimated total population.

The following crude death rates were obtained:

	CRUDE DEATH RATE		
	Males	Females	Both Sexes
Rural	18.2	18.9	18.5
Urban	15.2	16.1	15.7
Total	17.6	18.3	17.9

The estimated crude death rates (18.5 for rural areas and 15.7 for urban areas) appear to be reasonable in the light of some direct and indirect evidences [10]. Also the crude birth rate (40.1) which is derived by adding the crude death rate to the assumed growth rate also appears to be realistic.

Based on the observations in Table 8, a set of correction factors derived for each sex for rural and urban India are shown in Table 10 (Also see Figure 5). If it can be assumed that the degree of inaccuracies in the data will remain the same in the next few years, one could utilize these correction factors to rectify the reported annual number of deaths in rural and urban India.

Rectification of the Infant Death Rate

The infant mortality rate calls for special comment both in view of its importance as an indicator of social well-being and also because it is an area where the Indian demographic data are weak. In the past, the census actuaries have somehow assumed a value or a range of values for the infant mortality rate and proceeded to construct the census life tables. Depending upon the value assumed the estimates of expectancy of life at birth tended to vary [11]. Also the uncertainty in the level of the infant mortality rate introduced an element of uncertainty in the estimates of all vital rates.

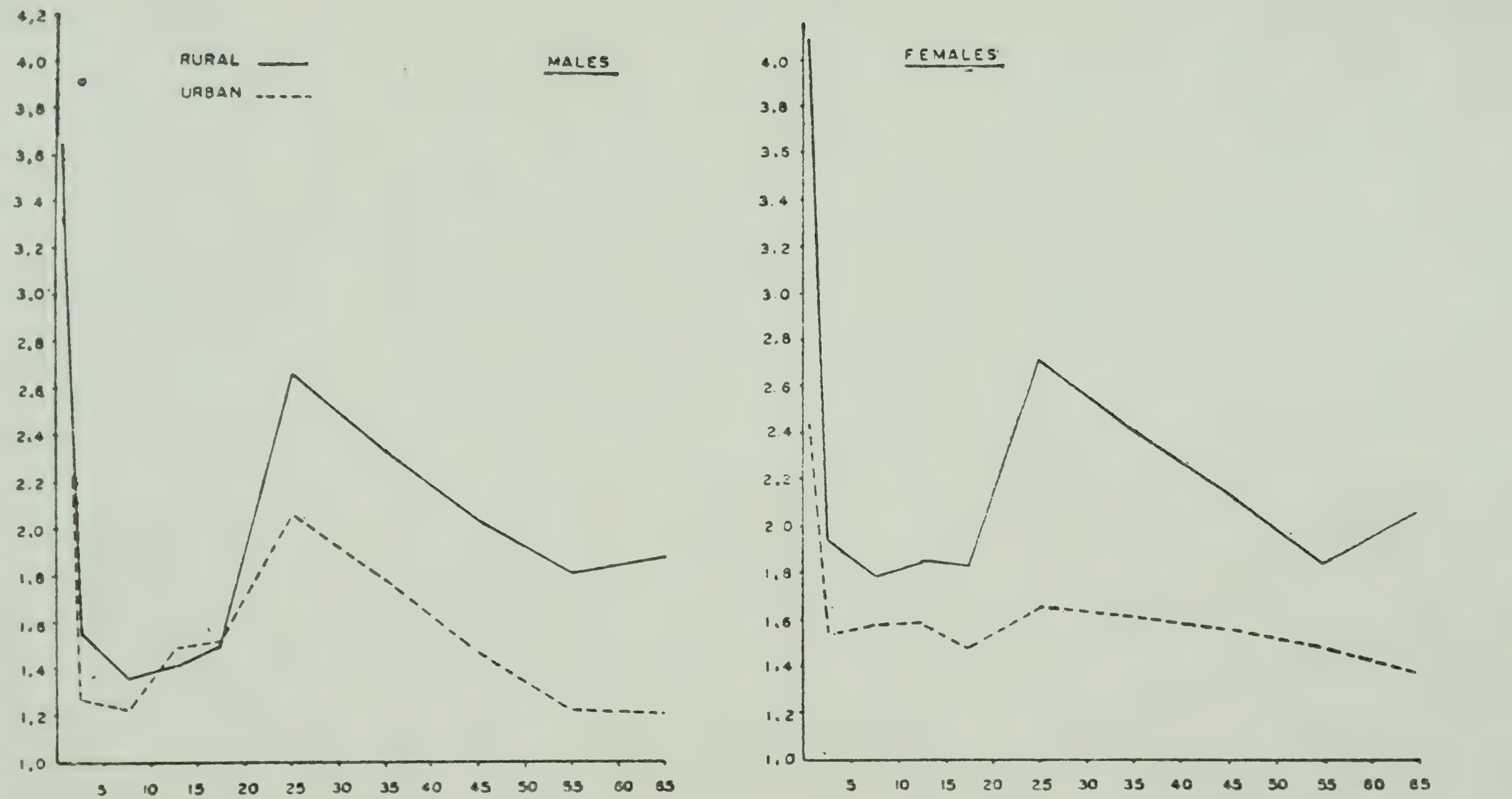

Fig. 5 : *Correction factors for sex-age specific death rates for rural and urban India, 1965-66*

Table 10

CORRECTION FACTORS FOR AGE SPECIFIC DEATH RATES

Age Group	Rural		Urban	
	Males	Females	Males	Females
0	3.64	4.11	2.21	2.44
1–4	1.55	1.95	1.27	1.55
5–9	1.35	1.79	1.21	1.58
10–14	1.40	1.86	1.48	1.59
15–19	1.50	1.83	1.52	1.49
20–29	2.67	2.72	2.06	1.66
30–39	2.34	2.41	1.79	1.61
40–49	2.04	2.14	1.47	1.56
50–59	1.81	1.84	1.22	1.48
60 +	1.88	2.06	1.21	1.38
All Ages	2.16	2.40	1.53	1.69

Source : Computed from Table 8.

According to our estimates the infant mortality rates in 1965-66 were 139.4 and 138.9 for males and females respectively in rural areas and 124.5 and 125.0 for males and females respectively in urban areas. These estimates are consistent with the limited direct evidence that indicate high infant mortality as well as indirect evidence based on the relationship between the crude death rate and the infant mortality rate [12]. The infant death rates for rural and urban areas derived here may therefore be taken as valid.

In order to correct the number of infant deaths classified according to age segments, several approaches were explored. In the first approach international data on infant deaths classified according to age were examined to arrive at the relationship between the infant death rate on the one hand and the rates for under one week, one week to one month, one month to six months and finally for six months to one year. The observed relationships could be utilized to estimate the infant death rates by age classes for rural and urban India. While the data did reveal clear positive relationships between infant death rates and those for the different age segments, there were several countries which deviated from the fitted relationship [13]. Part of the explanation for this may be the differing degrees of accuracy of the data for the different countries, but

partly there may be different regional and national patterns in infant mortality which may be influenced by different social and cultural factors. Therefore until these factors are investigated, international patterns could not be utilized to correct the data.

The second approach attempted to establish the relationship based on data for a few areas of India known for good registration. This was given up as the data were not sufficient for this purpose. The third approach which was finally adopted utilized the following average 1965-1966 proportions of infant deaths by age segments computed for major cities of India.

Table 11

RECTIFIED NUMBERS OF INFANT DEATHS AND INFANT DEATH RATES FOR RURAL AND URBAN INDIA, 1965-1966

	Rectified number of infant deaths (in thousands)			Rectified infant mortality rates (per 1000 livebirths)		
	Males	Females	Both Sexes	Males	Females	Both Sexes
Infant deaths (Under one week)						
Rural	292	233	525	51.8	43.1	47.6
Urban	58	46	104	46.3	38.3	42.5
Total	350	279	629	50.9	42.2	46.6
Infant deaths (One week to one month)						
Rural	167	159	326	29.7	29.5	29.5
Urban	33	32	65	26.3	26.7	26.5
Total	200	191	391	29.1	28.9	29.0
Infant deaths (One month to six months)						
Rural	183	190	373	32.5	35.1	33.8
Urban	36	38	74	28.7	31.7	30.2
Total	219	228	447	31.8	34.5	33.1
Infant deaths (Six months to one year)						
Rural	143	169	312	25.4	31.2	28.3
Urban	29	34	63	23.2	28.3	25.7
Total	172	203	375	25.0	30.7	27.8
Infant Deaths (Total under one year)						
Rural	785	751	1536	139.4	138.9	139.1
Urban	156	150	306	124.5	125.0	124.9
Total	941	901	1842	136.8	136.3	136.5

Suorce : Derived from Table 9.

These proportions on application to the estimated number of infant deaths yielded the number of infant deaths in different age segments shown in Table 11. A comparison of the estimated figures with the reported data shows that the discrepancies are acute in the case of the deaths occurring in the first week. This is attributable to the fact that infants who die soon after they are born are unlikely to be recorded in the birth and death registers. In the subsequent age segments the percentage of completeness gradually improves and in the last age segment (six months to one year) it is 40 per cent complete in rural areas and 53 per cent complete in urban areas, as seen from the following figures.

PERCENTAGE COMPLETENESS OF REGISTRATION OF INFANT DEATHS

	Rural		Urban	
	Males	Females	Males	Females
Under One week	18	17	40	39
One week to One month	24	20	36	31
One month to Six months	30	26	50	45
Six months and over	46	36	59	47
Under One year	27	24	45	41

These calculations show that the registration of all infant deaths is only 25 per cent complete in rural areas and 43 per cent complete in urban areas.

Comparison with earlier estimates

The estimates derived here show that mortality has further declined during 1956-1966, an observation consistent with what one should expect in the context of the socio-economic developments during this period. However the *extent* of the decline calls for some comment. If the official estimate of e_0^0 for the 1941-1951 and 1951-1961 decades are taken as correct, this would suggest that the improvement in the expectancy of life at birth during 1956-1966 has been only 6.0 years against an improvement of 9.1 years during the preceding 10 years. (see Table 12)

Table 12

COMPARISON OF THE PRESENT ESTIMATES WITH OTHER ESTIMATES

Source	Period	Expectancy of life at birth	Infant Mortality Rate	Crude Death Rate	Crude Birth Rate
1. Present Study	1965—66	47.2	137	17.9	40.1
2. Census Actuary	1941—51	32.1	183	27.4	39.9
	1951—61	41.2	146	22.8	41.7
3. Visaria	1941—51	33.1	236	30.0	42.6
	1951—61	37.4	202	25.7	44.9
4. Coale & Hoover	1951	32.2	225	31.0	43.2
5. Expert Committee	1966	50.2	118	15.6	39.8
6. Sample Registration	1968*	47.1	137	16.8	39.0

Sources :

1. Estimates derived in the preceding sections.
2. United Nations, *Demographic Yearbook,* 1966 pp. 574 and 594
3. P. M. Visaria "Mortality and Fertility in India, 1951-61" *Milbank Memorial Fund Quarterly,* Vol. XLVII. No. 1, Jan. 1969 Part 1, p. 111. The IMR shown is the average for both sexes derived from the rates in Coale-Demeny West Models associated with mortality levels 6.85 and 6.63 for males and females respectively in 1946 and levels 8.47 and 8.53 for males and females respectively in 1956.
4. Ansley J. Coale and Edgar Hoover, *Population Growth and Economic Development in Low income Countries, op. cit p. 38.*
5. *Report of the Expert Committee, 1968 op. cit* pp. 29-30. The figures shown are averages for 1961-65 and 1966-71. The IMR shown was arrived at by following the assumptions of the Expert Committee.
6. *Sample Registration Bulletin* Vol. 5 No. 2 (Oct.-Nov. 1971). The e_0^0 value is the average for both sexes estimated from Coale-Demeny West Models corresponding to the infant death rates shown in Col. 4.

* For rural areas only.

This is somewhat surprising in the context of the strides made in the field of public health during the second and third five year plans covering the period 1956-1966 [14]. Instead of a deceleration of the pace in improvement of life expectancy at birth from 0.9 year per annum during 1946—56 to 0.6 year per annum during 1956—66 noticed above, one should actually expect a more rapid improvement during the latter period. There are two possibilities that deserve examination in this context.

a. The estimate of expectancy of life at birth derived in this study may be an underestimate, or

b. The census actuary's estimate of expectancy of life at birth for 1951—61 may be an overestimate.

The direct evidences from the Sample Registration Scheme, and indirect evidences based on observations for areas with better registration mentioned earlier makes the first possibility, unlikely. On the other hand, these evidences seem to point out that the estimate of the expectancy of life at birth for 1951—61 arrived at by the census actuary may well be overestimated. The method adopted by the census actuary for the construction of life tables for 1951–61 is essentially one of obtaining survivors of different cohorts after smoothing the age distributions of 1951 and 1961, supplemented by an assumption regarding the infant mortality rate. The assumed infant mortality rates (153.2 for males and 138.3 for females in 1956) are far too low not only compared with those in model life tables [15], but also in comparison with the the infant mortality rates observed from the SRS for later years [16]. The underestimation of infant mortality alone may account for the high value of expectancy of life at birth obtained by the census actuary.

If instead of the census actuary's estimate, the estimates of e_0^0 made by Visaria (33.1 for 1941-51 and 37.4 for 1951-61) are taken as correct, then the improvement in expectancy of life at birth during 1956-66 works out to 9.8 years as against only 4.3 years during the preceding ten years. This would indicate that the pace of decline in mortality has indeed accelerated during 1956–66, as might be anticipated in the context of the expansion of health activity that had taken place during this period.

This is in accordance with the observations of United Nation regarding the pace of improvement in longevity associated with economic and social development, and expansion of health services. The United Nations study observed an acceleration of the pace of improvement in the initial stages, which is followed by a decrease in the pace when the "soft rock" causes of mortality are eliminated[17]. When the high rates of infant and maternal mortality and mortality due to infectious and parasitic diseases prevalent in India there is still considerable scope for elimination of the "soft rock" causes, and the present pace of improvement in longevity is likely to continue at least till the end of the present decade[18].

Final Remarks

This study shows that the death registration statistics for India, which are deficient in many respects, can be evaluated and rectified by utilizing the available supportive material from censuses, Sample Registration System and other sources, supplemented by international experience as embodied in the model life tables. The estimates of expectancy of life at birth (47.6 for males and 46.8 for females in 1965—66) derived in this study seem to suggest that the census actuary's estimates for 1951—61 are on the high side due to a possible underestimation of infant mortality rate for this period. This study also indicates that the pace of improvement in longevity has accelerated during 1956—66 compared to the preceding decade.

NOTES

1 The states included are Andhra Pradesh, Gujarat, Haryana, Kerala, Madhya Pradesh, Tamilnadu, Maharashtra, Mysore, Orissa, Punjab, Uttar Pradesh, West Bengal and Himachal Pradesh. The Union Territories of Delhi and Chandigarh are also included.

2 V. G. Valaoras, "Testing Deficiencies and Analytical Adjustments of Vital Statistics", *Proceedings of the World Population Conference*, Belgrade, 1965, Vol. III, pp. 190-194.

3 The Registrar General has estimated the underregistration to be 47.5 per cent for births and 41.5 per cent for deaths in rural areas in 1966. See *Vital Statistics of India*, 1966 p. viii Statement 3. The analysis in this paper shows that these estimates of degree of underregistraion are themselves far too low.

4 For example, Ansley Coale and Edgar Hoover estimated the birth rate to be 40.9 in 1961-65. See Ansley Coale and Edgar Hoover *Population Growth and Economic Development in Low Income Countries* Princeton : Princeton University Press, 1959 p. 38. The Expert Committee assumed a birth rate of 41.0 for 1961-1965 and 38.6 for 1966-1970. See Office of the Registrar General, *Report on the Population Projections Worked out Under the Guidance of the Expert Committee,* New Delhi 1968.

5 Based on information obtained from hospitals and health centres throughout the country during the period 1949-58, Ramachandran and Deshpande obtained all-India average of 106 male livebirths to 100 female livebirths, See K. V. Ramachandran and V. A. Deshpande "The Sex Ratio at Birth in India by Regions" *The Milbank Memorial Fund Quarterly*, April 1964 Vol. XLII No. 2 Part 1, p. 93.

6 See P. K. Nambiar and K. E. Vaidyanathan, *Demography and Vital Statistics Report for Madras State* Census of India 1961 Vol. IX Part I. B.

7 This rule of thumb is supported by the observation in the subsequent sections and Table 9, which show that the percentage of underregistration at ages one and over is about three-fifth of the percentage of underregistration of infant deaths.

8 The method adopted for arriving at the mortality level is the one recommended by the United Nations, See United Nations Manual IV. *Methods of Estimating Demographic Measures from Incomplete Data*, New York 1967 (ST/SOA/Series A/42) p. 7-30. In these calculations the Coale-Demeny, *Regional Model Life Tables and Stable Populations,* Princeton University Press, Princeton N. J. 1966.

9 The effect of a violation of this assumption on mortality is not likely to be as serious as the effects of age misreporting or underreporting of deaths.

[10] The direct evidence is from the Sample Registration Scheme (SRS) which gave an estimate of Crude Death Rate of 16.8 per thousand persons for rural India in 1968. The indirect evidence is provided by the crude death rates for major cities and special health areas which were 12 and 11 per thousand persons respectively in 1965-66. The rates for urban and rural areas should be higher than these figures.

[11] Coale and Hoover found that infant mortality rates of 200 and 250 are associated with expectancies of life at birth of 34.1 and 30.2 respectively. See Ansley Coale and Edgar Hoover *op cit* page 54.

[12] The direct evidence comes from the SRS which gave an infant mortality rate of 136.8 for 1968 in rural India. The indirect evidence is based on the relationship between the crude death rate and infant mortality rate derived by Coale and Hoover on the basis of data for Special Health Areas. (See Ansley Coale and Edgar Hoover *op cit* page 52-53.) The crude death rates obtained earlier are associated with IMRs of 140 and 125 respectively.

[13] Over 50 observations for 30 countries were assembled from the United Nations *Demographic Yearbooks*, 1951, 1961 and 1968 and plotted on a graph with infant mortality rates on the X-axis and the rates for different age segments on the Y-axis.

[14] As against an allotment of Rs. 140 crores for health programmes in the first plan, the outlay in the second & third plans were Rs 225 crores and Rs 341 crores respectively. During this period expansion of every sector of health activity is visible. See A. Chandrasekhar and G. R. Nair, "The Administrative Implications of Rapid Population Growth in India" *EUROPA Conference on Administrative Implications of Rapid Population Growth in Asia,* Manila, May 1971.

[15] The infant mortality rates associated with e_0^0 of 41.89 for males and 40.55 for females are 172 and 178 respectively.

[16] The SRS yielded an infant mortality rate 136.8 per thousand livebirths in rural areas in 1968. The rates for 1956 should have been considerably higher than this figure.

[17] United Nations, *Population Bulletin No. 6, with Special Reference to the Situation and Recent Trends in Mortality in the World,* pp. 48-49.

[18] The Expert Committee which worked out the population projections for India upto 1986 assumed that the expectancy of life at birth will improve at the rate of 0.9 and 0.75 years per annum during 1956-70 and 1971-80 respectively. See *Report of the Expert Committee op cit* p. 7. While the assumption seems to be justified, the resulting estimate of expectancy of life at birth for 1966 (50.9 for males and 49.6 for females) seems to be overestimated because the base figures for these calculations namely the census actuary's estimate of e_0^0 for 1951-61 are on the high side.

Infant Death Rates in Poona City: An Evaluation

Kumudini Dandekar and Vaijayanti Bhate

Anyone familiar with Indian vital registration knows how risky it is to give a single dependable value for infant mortality for any part of the country. The construction of life table for any region of the country is therefore often based on alternative assumptions regarding infant mortality. These alternatives often covered a big range of values between which the truth is expected to lie. In this paper we have examined the registration data for Poona city in Maharashtra State in order to throw light on the extent of errors in the infant death rates in a premier metropolitan city of India. In this evaluation we have utilized certain assumed relationships between the extent of accuracy of birth rate, death rate and infant death rate.

To get a rough check on the registered infant mortality rate for the city of Poona, the association between the crude death rate and the corresponding infant mortality rate as observed by Ansley Coale and Edgar Hoover[1] was utilized. Coale and Hoover worked out the association between crude death rate and infant mortality rates in some areas of India known for their good registration. This included Singur (1947-50 and 1951-54) and the suburbs of Calcutta in West Bengal, Ramanagaram in Mysore State, Sirur in Maharashtra State and Poonamallee in Madras State, most of which were observed in the early fifties. The association observed by them is shown in Graph I, where crude death rates based on deaths at all ages are put on the X-axis and the infant mortality rates on the Y-axis. Though the association observed in Graph 1, related to non-city areas, the relation could hold good, at least broadly, for the city of Poona too. Hence the values of the registered infant mortalily rates and corresponding crude death rates for the eighteen years from 1948 to 1966 were put on the same graph.

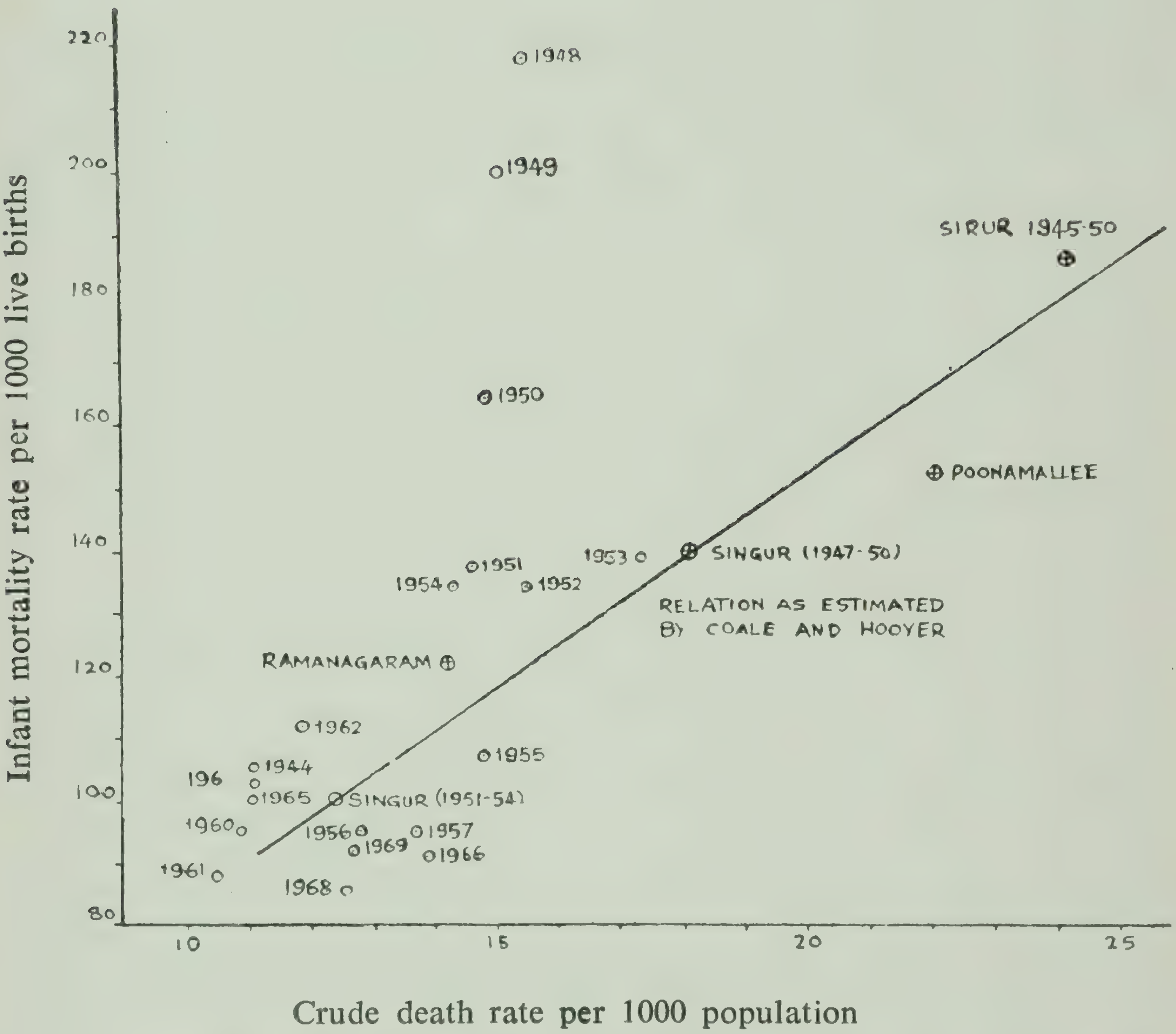

Fig : 1 *Registered crude and infant mortality rates in Poona city for various calendar years*

Two points are striking. Firstly, the registered infant mortality rates for the early years of nineteen-fifties and for the period prior to 1950 were higher than those estimated on the basis of the Coale-Hoover line. Secondly, the points representing later years though fell in line with the Coale and Hoover regression line, their location was not clustered about the line. For consecutive years they seemed to be concentrated either below or above the line. These deviations can only be explained partly by errors in the registered death and infant death rates and partly by the possibility of regression line being changed. Since infant mortality rates are ratios of infant deaths to live births the errors in the infant mortality rates can arise from the deficiencies in the registration of births as well as of infant deaths. In short, the registered rates needed correction, both for under-registration of births as well as deaths and especially the infant deaths.

In Table 1, the number of registered live births, infant deaths and their number per thousand live births are set out for inspection. The number of births in the city increased from about 14,000 to more than 23,000 during 1951 to 1966.[3] The average number of infant deaths on the other hand remained a little less than 2000, throughout the period under consideration. Naturally the infant death rate obtained from the ratio of infant deaths to live births decreased by one-third during this period from about 137 in 1951 to 91 in 1966. Some explanation seemed necessary for an observed trough in the number of infant deaths and the death rate for the years 1956 to 1961. But otherwise the trend of infant death rate seemed trustworthy although its levels may not be equally accurate at all points of time.

The Infant Mortality rate is affected by two kinds of errors :

a. Deficiencies in the reporting of births, and
b. Deficiencies in the reporting of infant deaths.

Table : 1

NUMBER OF LIVE BIRTHS AND INFANT DEATHS REGISTERED IN THE POONA MUNICIPAL CORPORATION AREA AND INFANT DEATHS PER 1000 LIVE BIRTHS FOR VARIOUS CALENDAR YEARS, 1951 - 1966

Calendar year	Registered live births	Registered infant deaths	Infant deaths per 1000 live births
1951	14,370	1,974	137.4
1952	14,704	1,975	134.3
1953	13,956	1,935	138.7
1954	14,191	1,895	133.5
1955	17,510	1,878	107.3
1956	16,995	1,611	94.8
1957	17,624	1,676	95.1
1958	17,104	1,454	85.0
1959	16.650	1,525	91.6
1960	16,436	1,563	95.1
1961	17,385	1,524	87.7
1962	16,183	1,813	112.0
1963	18,268	1,874	102.6
1964	19,904	2,084	104.7
1965	20,636	2,063	100.0
1966	22,952	2,091	91.1

Source: The vital registration records of the Poona Municipal Corporation.

Both these possibilities may be examined. To begin with, we may consider the question whether the registration data on births are trustworthy. In orded to assess their reliability we present in Table 2, the birth rates for the city along with the sex-ratios among live births in terms of males per hundred females.

Table 2

REGISTERED BIRTH RATES AND SEX RATIOS AMONG LIVE BIRTHS FOR POONA MUNICIPAL CORPORATION, 1951 - 1966

Calendar Year	Birth rate	Sex ratio among live births
1951	29.9	106.4
1952	29.9	109.9
1953	27.8	110.4
1954	27.6	105.5
1955	33.4	109.5
1956	31.7	107.4
1957	32.2	105.0
1958	30.6	103.5
1959	29.1	107.4
1960	28.1	107.7
1961	29.1	108.6
1962	24.7	105.7
1963	27.3	107.7
1964	29.1	107.8
1965	29.5	110.7
1966	32.2	110.6

(a) Deficiencies in the Registration of Births

The birth rates observed in Table 2, appeared generally lower for the period under consideration and especially so for the early fifties. They increased from 26 to 33 births per thousand of population during 1950–55 and decreased from 33 to about 29 births per thousand population during 1955–65[3]. Such results not being anticipated raised doubts regarding the registration data. There was no reason to have a birth rate much lower than 40 births per thousand of population observed nearabout 1950. Contraceptive practice was rare in this period. Moreover the results of the sample survey in 1951 yielded a birth rate of about 40.0 per thousand of population[4]. The census of 1951 also did not reveal a low birth rate for that year. There were thus strong reasons for doubting the registration data on births nearabout 1951. The boundaries of the city had changed in 1951 when Poona City Municipality attained the status of a

Corporation. The area of the city changed from 18 square miles to 50 square miles with such change in status. With the major changes in the boundaries, there is often a time lag before the efficiency in administration reaches all the quarters. That is why perhaps the registered rate of births increased from 26 to 33 during 1951 to 1955.

The suspicion regarding reliability of birth registration was further strengthened by the reports from the Department of Vital Registration for the city. According to them increasing efforts were being made in order to improve the vital registration of the city but still without complete success till 1966. They reported that any attempt at combing out unregistered births especially in the slums of the city revealed some unregistered events even in 1966 and this indicated underregistration of births in the city.

The sex-ratio at birth is a biological factor not expected to have much regional variation. Very often the value of the sex-ratio at birth assumed for India is nearabout 105 males per 100 females. Occasionally a range of values like 104 to 107 male births to 100 female births is assumed for the Indian communities. The sex-ratios observed in the registered births for various regions in the country varied so much that one did not trust them. The ratios observed in the 15th round of N. S. S. (2nd subsample) varied from 96 to 125 male births per hundred female births in various states of the country. In most of the countries that have reliable data the sex-ratio at birth was observed to be 105 or 106. The ratios observed in various states in India could often be the result of underreporting of female births. One therefore wondered whether there was underregistration of female births in the city of Poona too. The sex-ratio at birth for the city given in Table 2, consistently indicated a value nearabout 108 male births to 100 female births. The value was observed to be comparatively regular in the registration of the city for all the 18 years under observation in spite of the probable changes in the level of reliability of the registered data during 1948-1966. In other words, with more reliable registration data, there is no recognizable change in the sex-ratio at birth. This perhaps meant that the underreporting of births, if any, was not restricted more to one sex than to the other.

(b) Deficiencies in the Reporting of Infant Deaths

The number of infant deaths in the city remained nearabout two thousand during the period under consideration (see Table 1). This was observed in spite of the rise in the population of the city. But since the infant mortality rate was supposed to have declined during this period, one could believe in almost a constant number of infant deaths observed in the register except for recognizable underreporting in 1956 to 1961. However there has been a steady decline in the infant death rates especially after 1961 which is in accordance with our expectations.

If one suspected registration of births, one should also suspect the registration of infant deaths, particularly of those deaths occuring in the very early period of life. Some births perhaps remained unregistered because of early deaths among the births. Earlier the death, the greater the possibility of its being missed. According to estimats of underregistration of births and deaths by the Office of the Registrar General the proportion of unregistered births was always smaller than or equal to the proportion of unregistered deaths in most of the States.[5]. Therefore if (a) the proportion of unregistered births was smaller than or equal to the proportion of unregistered deaths, and if (b) the underregistration was assumed to be mostly restricted to infant deaths,[6] then the expected infant mortality rate for the city of Poona was bound to be larger than the registered infant mortality rate. The above observations have been utilized in the subsequent sections for evaluating and adjusting the infant mortality rates for Poona city.

Correction of Registration Data on Births

Assuming that the birth rate for Poona was about 40 births per thousand in 1951 as observed in the survey of the city the rates for the following calendar years were estimated on the basis of the expected decline in birth rate as a result of the number of sterilizations and other contraceptive practice. The registered birth rates were compared with the expected rates for the corresponding years and estimates of the percentages of underregistration of births were obtained. The percentages of unregistered births given in the last column of Table 3, do not seem untrustworthy. Only the figure for 1964 looked suspiciously low. A reasonable value that could be

Table 3

THE ESTIMATED PERCENTAGES OF UNDERREGISTRATION OF BIRTHS IN VARIOUS CALENDAR YEARS, 1951 - 1964

Calendar Year	Expected birth rate per 1000*	Registered birth rate per 1000**	Estimated percentage of underregistration
1951	40.0	29.9	25.3
1952	39.9	29.9	25.0
1953	39.6	27.8	29.8
1954	39.2	27.6	29.5
1955	38.7	33.4	13.7
1956	38.2	31.7	17.0
1957	37.6	32.2	14.4
1958	36.9	30.6	17.2
1959	36.1	29.1	19.4
1960	35.1	28.1	19.9
1961	33.9	29.1	14.1
1962	32.8	24.7	14.3
1963	31.9	27.3	14.4
1964	31.4	29.1	7.3

* Estimated on the basis of a birth rate of 40 at the beginning and the estimated number of births prevented every year as a result of sterilization and other contraceptive practice. For more details see Chapter IV of *Prospects of Population Control - Evaluation of Contraception Activity* by Kumudini Dandekar and Vaijayanti Bhate. Gokhale Institute Studies No. 58.

** Not estimated due to its inconsistency with the trend observed for other years.

assumed for 1964 was 14 instead of 7 for consistency with immediately preceding years. In that case the estimate of birth rate in the second column will be 33.8 births per 1000 population for the year 1964.

Correction of Registration Data Regarding Deaths and Infant Deaths

On the assumption stated earlier the underregistration of deaths was considered to be of the same order as that of births and further that the failure to register deaths was mostly due to failure to register infant deaths. On the basis of this assumption the numbers of unregistered infant deaths were calculated. They are shown in Table 4. Prior to 1955 the underregistration of births and deaths was of a different order than from 1955 onwards. It may possibly

Table 4

THE INFANT MORTALITY RATES CORRECTED FOR UNDERREGISTRATION, IN THE CITY OF POONA, 1951 - 1964

Calendar year (1)	Estimated percentage of un-registered deaths (2)	Registered total deaths (3)	Total deaths corrected for under-registration (4)	Estimate of un-registered deaths (4)−(3) (5)	Registe-red infant deaths (6)	Expected number of infant deaths (5)+(6) (7)	Infant mortality rate corrected for under-registration (8)	Modified estimate of infant mortality rate (9)
1951	25.3	7,016	9,392	2,376	1,974	4,350)	226.1)	162.1
1952	25.0	7,607	10,143	2,536	1 975	4,511)*	230.0)*	159.8
1953	29.8	8,684	12,370	3,636	1,935	5,621)	282.6)	157.5
1954	29.5	7,321	10,384	3,063	1,895	4,958)	246.4)	155.2
1955	13.7	7,788	9,024	1,236	1,878	3,114	153.4	152.9
1956	17.0	6.887	8,298	1,411	1,611	3,022	147.6	150.6
1957	14.4	7,522	8,787	1,265	1,676	2,941	142.8	148.4
1958	17.2	7,063	8,530	1,467	1,454	2,921	141.4	146.1
1959	19.4	7,242	8,985	1,743	1.525	3 268	158.3	143.8
1960	19.9	6,399	7,989	1,590	1,563	3,153	153.7	141.5
1961	14.1	6,273	7,303	1,030	1,524	2,554	126.1	139.2
1962	N.A.	7,239	N.A.	N.A.	1,813	N.A.	N.A.	136.9
1963	14.4	7,017	8,197	1,180	1,874	3.054	143.1	134.6
1964	7.3	7,090	7,648	558	2,084	2,642	123.1	132.3

Col. (2) : Estimated on the assumption that the extent of underregistration of all deaths is the same as that of live births.

Col. (4) : Estimated by the formula $T=R/(1-u)$ where T and R are the true and registered total deaths and u the degree of underregistration.

Col. (7) : Estimated on the assumption that all unregistered deaths are infant deaths.

Col. (8) : Estimated by relating infant deaths in Col. 7 to the number of live births corrected for underregistration.

Col. (9) : Estimated on the basis of regression line fitted to the infant mortality rates (in Column 9) for the period 1955 to 1964.

* Unreliable as explained in the text.

be due to a lag between the change in the boundaries of the city and the attainment of comparable efficiency in registration in the areas newly included in the city boundaries.

If the registered number of births and deaths was corrected as discussed above, the association between the crude death rates and infant mortality rates could be re-examined. The corrected rates are presented in Graph 2. An independent regression line was fitted for the city of Poona, ignoring the observations before 1955 since the degree of registration in the early fifties was not on par with those for subsequent years, and consequently the assumption that underregistration of deaths is confined to infant deaths could not hold good for this period to the same extent as for the later years.

The regression line between infant and crude death rates for Poona city is shown in Graph 2 along with the Coale-Hoover Regression line. Two points may be noted about the difference between the two. One is that the regression line for Poona city gives higher infant mortality rate than the rates observed for non-city communities from the Coale and Hoover regression line. Secondly, the slope of the regression line for Poona city is slightly smaller than that for the non-city areas. These could lead to two conclusions. The contribution of infant mortality to total mortality in the city was slightly higher than that in the non-city area. It is difficult to explain why this should be so, although the congestion in cities like Poona may be one possible factor[7] explaining relatively higher infant mortality there. Secondly, the fall in infant mortality rates for a unit decline in crude death rate is slightly smaller in the city than in the non-city area. The latter difference is however very small and could be neglected.

In the absence of any other better method of estimation, the infant mortality rates for the survey years 1951 to 1964 were adjusted by fitting a straight line to the corrected infant mortality rates for the period 1955 to 1964. These are set out in the last column of Table 4. The estimates of infant mortality rates for 1951 and 1964 were 162 and 132 deaths per thousand live births respectively. This indicates a decline of about one fifth in a little over a decade The estimated infant death rate of 150 for 1956 is

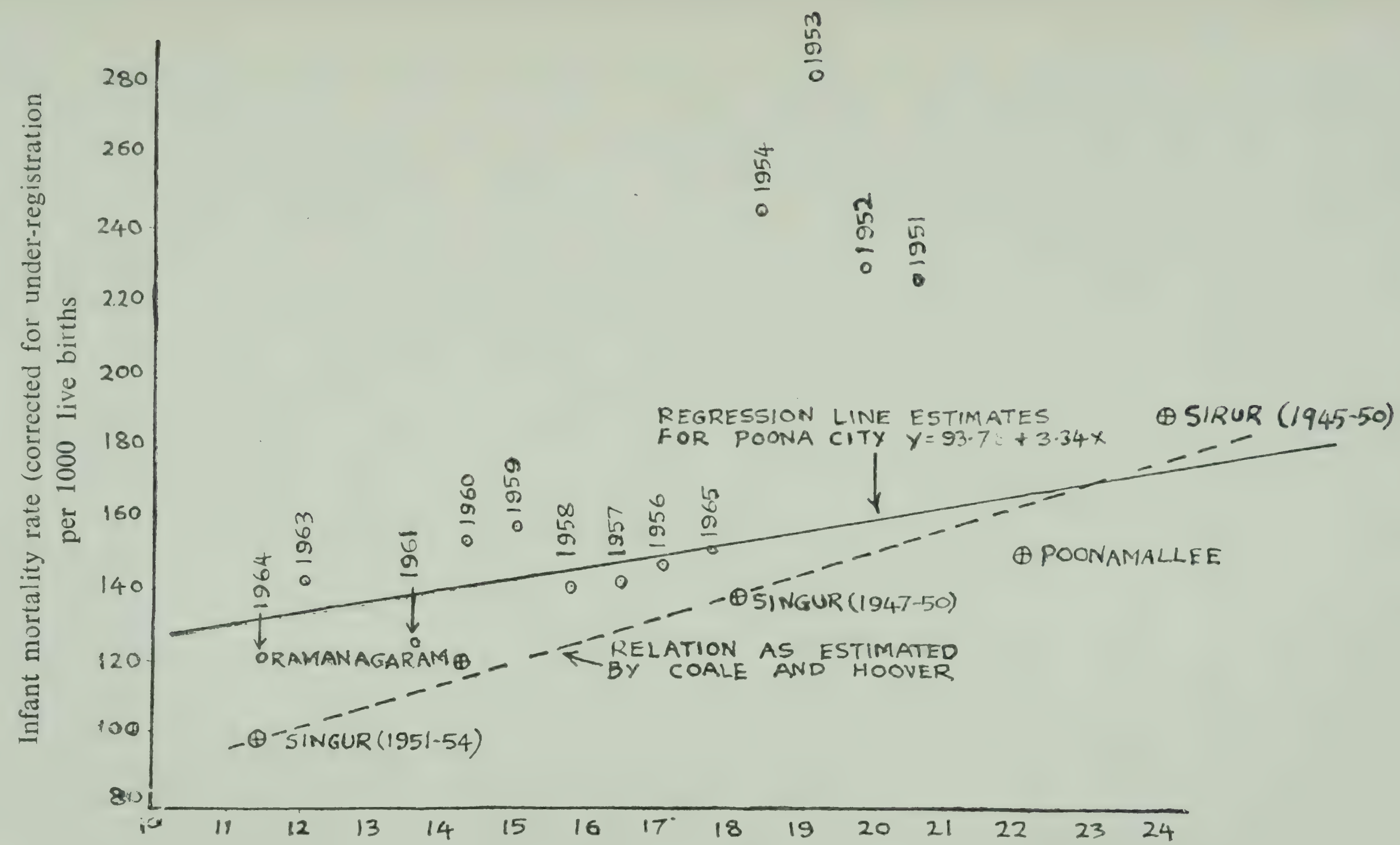

Fig : 2 *Crude death rates (corrected and smoothed) and infant mortality rates (corrected) in Poona city for various calendar years*

higher than the infant death rates for the mid 1651-1961 decade assumed by the census actuary for All-India. It is difficult at this stage to compare the levels of infant mortality in a city like Poona with that of the country as a whole, and this calls for improved data and detailed evaluations.

Concluding Observations

This paper attempts an examination of the registration data on infant death rate for errors arising from deficiencies in the registration of births as well as infant deaths. The departure of the observed data for Poona from those based on the Coale-Hoover regression line between infant death rates and crude death rates seem to indicate deficiencies both in the registration of births as well as infant deaths. The birth rates are adjusted with reference to other evidences including contraceptive practice, and on the assumptions that (1) the extent of underregistration of deaths is of the same order as that of births and (2) the underregistration of deaths arises mainly on account of underregistration of infant deaths, it is possible to estimate the infant death rates for the different years. An examination of the relationship between these corrected death rates and infant death rates seemed to indicate that at least for the earlier part of the period under consideration, the assumptions made are not valid. It was therefore decided to adjust these estimates by means of a linear equation fitted to the estimates for the period 1955 onwards.

The estimates obtained after this adjustment seem to be trustworthy ; the estimates of infant death rates for Poona city for 1951 and 1964 came to be 162 and 132 respectively, as against the registered infant death rates of 137 and 105. There has been little improvement in the degree of accuray of infant death rates as measured by the ratio of the registered rate to the estimated rate. The decline in the infant death rate during the intervening period is only of the order of one-fifth, which is surprisingly very small. Not only is the level of infant death rates higher than those generally assumed, the decline in the infant death rate during a period of economic development is smaller than anticipated. These call for further investigation which will be possible only if more reliable and representative data become available for the entire country.

NOTES

1 See Ansley J. Coale and Edgar Hoover, *Population Growth and Economic Development in Low Income Countries*, Princeton, N. J. Princeton University Press, 1959, p. 53.

2 The data prior to 1951 may not be strictly comparable with the figures for subsequent period due to changes in the boundary of the city; moreover the municipality of Poona attained Corporation status in 1950.

3 The slight increase in birth rate in 1966 may be fortuitous due to errors in mid-year population estimates or fluctuations in the numbers of births.

4 *Survey of Fertility and mortality in Poona District* (Publication No. 27 of the Gokhale Institute, Poona) by V. M. Dandekar and K. Dandekar.

5 Registrar General, India, *Vital Statistics of India*, 1961 page KL of Introduction.

6 This could be true only when the extent of underregistration was below a specific level. In the case of Poona city this could be assumed without being much in error.

7 A study by Vaidyanathan for Madras city shows higher infant mortality in slums and other congested areas of Madras city. See Census of India, 1961 Vol. IX Madras State Part IB. *Demography and Vital Statistics Report*. Chapter on Mortality Differentials.

Measures of Mortality from Indian Sample Registration System

V. K. Ramabhadran and V. S. Swamy

Introduction

In this paper, some measures of mortality for India are presented based on the data collected through the Sample Registration System (SRS). The Sample Registration System (SRS) is a miniature registration system in a random sample of villages and urban blocks with a local enumerator recording continuously the births and deaths as they occur coupled with a periodic survey by a supervisor. This system thus combines the advantages of continuous registration and a retrospective survey once in six months. After the completion of the six-monthly survey, the results of the survey are compared with the local enumerator's record. Matching is done item by item. The partially matched and unmatched events are re-verified in the field and an unduplicated count of events is then obtained[1]. In respect of the death events, the recorded information includes the age of the deceased, sex and other related particulars. The scheme was extended to urban areas of most of the states only in the latter half of 1969 and therefore the data from SRS for urban areas are available only for a few of the states. The available data for rural and urban areas are utilized for deriving several measures of mortality described in the subsequent paragraphs. It should be pointed out that the estimates may be affected by sampling fluctuations and also by the possibility of a violation of the independance of the two sourees of records on the basis of which these estimates are derived.

The Crude and Standardized Death Rates

The simplest measure of mortality is the crude death rate defined as the number of deaths in a year divided by the mid-year population of that year, multiplied by the factor 1000. This measure

does not take into consideration the age and sex composition of the population. Consequently, to provide a meaningful comparison of the levels of mortality in rural and urban areas, the standardized death rates have been worked out with the estimated population of India in 1968-1969 as the standard. The estimates of crude and standardized death rates for rural and urban India for the years 1968 and 1969 are presented below :

Table 1

CRUDE AND STANDARDIZED DEATH RATES FOR INDIA, 1968 AND 1969

	1968	1969
Crude Death Rate		
Rural	1.8+	19.1++
Urban	—	11.4+++
Standardized Death Rate		
Rural	17.9	18.4
Urban	—	14.0

Source : Data from Indian Sample Registration System. See Office of Registrar General, India, *Measures of Fertility and Mortality in India,* S.R.S. Analytical Series No. 2, 1972.

Footnotes : +Excludes Bihar, Haryana, Himachal Pradesh, Madhya Pradesh, Nagaland, Orissa, Tamilnadu, West Bengal and Union Territories.

++Excludes Bihar, Himachal Pradesh, Madhya Pradesh, Nagaland, Orissa, West Bengal and Union Territories.

+++Data relates to only six states, namely, Assam, Jammu-Kashmir, Mysore, Punjab, Rajasthan and Uttar Pradesh.

It is evident from the above Table that mortality is definitely lower in urban areas when compared with rural areas[2]. This is a reflection of the relatively greater availability of medical, public health, sanitation and drainage facilities in urban areas. The rural-urban differential in mortality observed here manifests itself in every measure of mortality presented in the subsequent sections.

Infant Mortality Rate

Mortality takes a heavy toll in the first year of life. The infant mortality rate refers to the ratio of the total number of annual infant deaths below one year to the total number of births in the same year multiplied by 1000. The infant mortality rate is often considered as an index reflecting the state of public health and hygiene, environmental sanitation, cultural and socio-economic development. Mortality during the first year of life can be broken up into two main phases, namely neo-natal mortality, occurring during the first four weeks and post-natal mortality occurring within the remainder of the first year of life after birth. The neo-natal mortality rate serves as an approximate index of that component of infant mortality which is attributable to endogenous factors, while the post-natal rate serves as an index of exogenous factors of infant mortality[8]. The latter is amenable to environmental and medical control than the mortality occurring shortly after birth. Table 2 presents the infant mortality rates by sex and age for rural and urban India.

Table 2

INFANT MORTALITY RATE BY AGE AND SEX, RURAL AND URBAN INDIA, 1968 AND 1969

		Infant Mortality Rate				
	Sex	Below 7 days	7 to 28 days	29 days to 6 months	7 - 12 months	Total
Rural, 1968	M	46.0	33.4	35.7	20.9	136.0
	F	40.4	27.9	42.5	26.9	137.7
Rural, 1969	M	44.4	29.4	48.1	20.4	142.3
	F	41.0	34.9	47.7	24.5	148.1
Urban, 1969	M	33.9	20.6	26.3	13.9	94.7
	F	24.2	17.4	28.0	13.0	82 6

Source: Data are from Indian Sample Registration System. See Office of Registrar General, India, *Infant Mortality in India, S.R.S. Analytical Series No. 1,* 1971.

Footnotes: See Table 1.

The neo-natal infant mortality rates for rural India in 1968 and 1969 are respectively 74 and 75 per 1000 live births, and 48 for urban India in 1969. It is observed that neo-natal mortality rate exceeds post-natal mortality rate which was 65 and 41 respectively for rural and urban India in 1969. About 55 per cent of infant deaths occur in the first month in rural India and the rest is spread over the other age groups below one year. In urban India about one-third of the infant deaths occur in the first month. The risk of death is greatest during the first week of life and decreases thereafter. It is observed that the risk of death is greater in the case of male infants than female infants during the first week after birth. In the case of infants surviving after one month, male infants have a slightly greater chance of survival than female infants.

In some cases infant deaths may have been mis-classified as still births due to ignorance especially when the cases of delivery are handled by inexperienced persons. Another measure which avoids the effect of such mis-classification is the perinatal mortality rate defined as the ratio of infant deaths below one week plus still births to total pregnancies (live births plus still births) multiplied by 1000. Table 3 gives the perinatal mortality rate by sex.

Table 3

PERINATAL MORTALITY AND STILL BIRTH RATES BY SEX, RURAL AND URBAN INDIA 1968 AND 1969

	Perinatal mortality rate		Still birth rate	
	Males	Females	Males	Females
Rural 1968	69.9	59.9	25.1	20.3
Rural 1969	67.8	59.5	24.5	19.4
Urban 1969	43.9	37.1	10.4	13.4

Sources and Footnotes: Same as for Table 2.

It is observed that peri-natal mortality rate for males is greater than that for females in both rural and urban areas. A similar pattern of difference is observed in the case of still birth rates. Once again we find that the rates for urban areas are lower than those for rural areas.

Age-Sex Specific Death Rates

It would be instructive to analyse the age-sex specific mortality rate which is defined as the ratio of the number of deaths in the specific age-sex group to the population in that group (See Table 4). It is seen from above that the pattern of age specific death rate is nearly U-shaped. In the youngest age-group, mortality is very high, thereafter it drops precipitously till it reaches the lowest level in the age group 10-14 for females and 15-19 for males. Then the curve gradually rises upto age 49 and from age 50 onwards, the curve rises sharply. The level of mortality in rural areas is slighly higher in 1969 than in 1968 which may be due to sampling fluctuations. In the youngest age group (0–4), females have higher mortality rate than males, and gradually, the difference between the sexes gets narrowed till the middle of teen ages. From age 15 onwards, when the females enter the reproductive age group, the mortality rates for females is higher than those for males. The above sex difference in mortality is marked in the age group (20-34) reflecting the effect of high maternal mortality rates prevalent in India. From age 45 onwards, male mortality rates are higher than female mortality rates. The pattern of age-sex specific death rates for urban areas is similar to that for rural areas but at comparatively lower levels (See Figure 1).

Comparison with Japan and Ceylon

The percentages of total deaths by age for each sex in Rural India are compared with those for Japan and Ceylon in Table 5 to bring out the differences in mortality patterns associated with differing socio-economic conditions (See F. 2) In the case of India, the percentage of deaths in the age group (0-4) is eight to ten times the percentage for Japan. In India over one-half of the total deaths pertains to the age group (0-4), while in Japan only one in twenty relates to the age group (0-4). In the age group 5-9 the proportion of deaths is about 5 per cent in India as against lesss than one per cent in Japan and about 3 per cent in Ceylon. In older age groups, the proportion of deaths increases more rapidly in Japan than in India possibly due to the effect of aging of population. From age 50 onwards the proportion of deaths in India is smaller

Table 4

AGE-SEX SPECIFIC DEATH RATES FOR RURAL AND URBAN INDIA 1968 AND 1969

Age Group	Rural 1968		Rural 1969		Urban 1969		Difference F — M as % of F			Difference R — U as % of R 1969	
	Males	Females	Males	Females	Males	Females	Rural 1968	Rural 1969	Urban 1969	M	F
0-4	59.12	66.82	58.32	70.16	43.16	47.06	11.52	16.88	8.29	25.99	32.93
5-9	5.53	6.26	5.79	7.71	3.67	5.45	11.66	24.90	32.66	36.61	29.31
10-14	2.26	2.60	2.99	2.72	1.85	1.56	13.08	−9.93	−18.59	38.13	42.65
15-19	1.99	3.34	2.09	4.22	1.58	2.82	40.42	50.47	43.97	24.40	33.18
20-24	2.65	5.09	3.88	5.54	1.70	5.89	47.94	29.96	71.14	56.19	—6.32
25-29	3.19	6.92	3.73	5.50	2.82	3.20	53.90	32.18	11.87	24.40	41.82
30-34	3.76	5.98	4.07	6.35	2.69	5.11	37.12	35.91	47.36	33.91	19.53
35-39	6.23	6.09	6.54	6.05	2.44	4.35	−2.30	-8.10	43.91	62.69	28.10
40-44	7.67	7.92	8.52	7.60	7.58	5.59	3.16	−12.11	−35.60	11.03	26.45
45-49	12.68	9.18	13.17	9.36	11.53	8.03	−38.13	−40.71	−43.59	12.45	14.21
50-54 } 55-59	18.99	15.35	22.36	17.76	15.15	9.10	−23.71	−25.90	−66.48	—	—
										—	—
					20.46	15.23			−34.34	—	—
60 +	65.08	60.34	71.21	66.48	63.49	56.76	−7.86	−7.11	−11.86	10.84	14.62

Source : Data from Indian Sample Registration System.

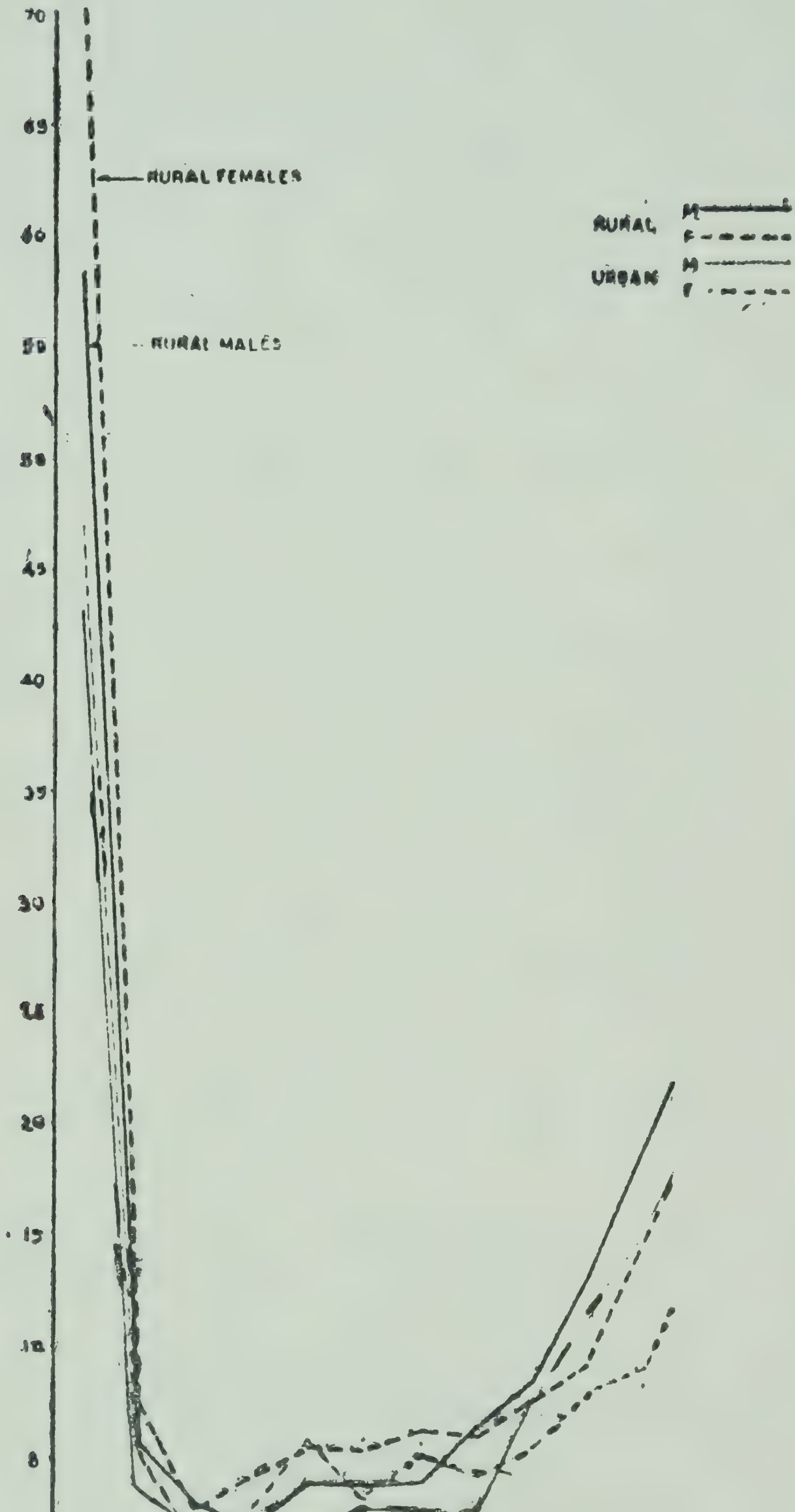

Fig 1 : *Age-Sex specific death rates for Rural & Urban India, 1969*

Table 5

PERCENTAGE OF DEATHS BY AGE IN SOME SELECTED COUNTRIES

Age Group	Japan (1967)		Ceylon (1967)		Rural India (1969)	
	M	F	M	F	M	F
0-4	5.70	5.02	28.96	32.13	50.47	54.98
5-9	0.67	0.47	2.88	3.58	4.55	5.23
10-14	0.54	0.38	1.60	1.79	2.06	1.62
15-19	1.43	0.79	1.77	1.87	1.04	1.79
20-24	1.71	1.05	2.08	2.31	1.51	2.20
25-29	1.84	1.32	1.92	2.39	1.42	2.03
30-34	2.11	1.53	1.72	2.14	1.48	2.25
35-39	2.72	1.94	2.60	2.79	2.13	1.75
40-44	3.00	2.41	2.57	2.02	2.51	1.98
45-49	3.21	3.04	3.82	2.53	3.12	1.87
50-54	4.87	4.17	3.88	2.77	4.11	3.06
55-59	7.55	5.73	4.98	3.37	3.88	2.41
60-64	10.19	7.34	5.56	4.18	6.23	5.06
65-69	13.35	10.21	7.32	5.90	4.36	3.44
70 and above	41.11	54.60	28.34	30.23	11.13	10.33
All ages	100.00	100.00	100.00	100.00	100.00	100.00

Source : Figures for Japan and Ceylon are from UN *Demographic Yearbook*, 1968. Figures for India are from Table 4.

than those observed for Ceylon and Japan. As regards sex differences in mortality in India, in the younger age group (0-4) the proportion of female deaths is more than the corresponding proportion of male deaths. A similar situation prevails in Ceylon, but the opposite pattern is observed in Japan. Mortality rates among females in the age group (15-44) is higher than the corresponding mortality rates among males in India and Ceylon. Consequently the proportion of total deaths in the age group 15-44 is higher among females than among males both for India and Ceylon but it is quite the opposite in the case of Japan. The proportion of total deaths in the age group 70 and over is higher for females in Japan and Ceylon as compared to a higher proportion for males in India.

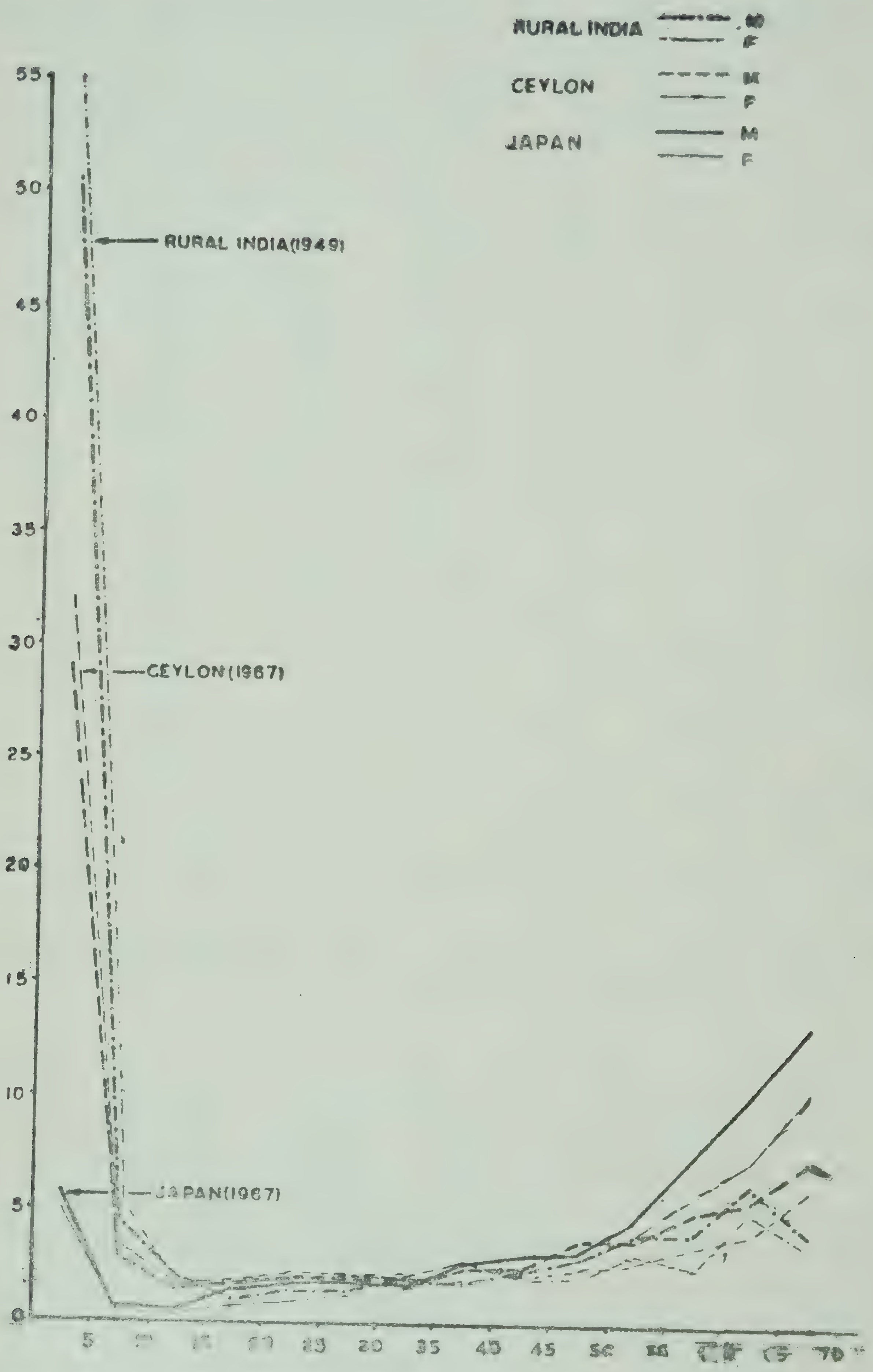

Fig 2 : *Percentage of total deaths by age, SRS estimates for Rural India, (1949) Ceylon, (1967) Japan, (1967)*

The differences observed above are in accordance with our expectations. It may be inferred that the SRS data provide a fairly correct picture of the overall patterns of mortality in the country and also the rural-urban and male-female differentials in mortality.

Summary and Conclusion

This paper utilizes the data from the Sample Registration System of India to present some measures of mortality for India for the years 1968 and 1969 by which period the scheme had developed and stabilized and consequently the available data may be taken as fairly accurate. The crude death rates for 1969 works out to 19 per 1000 for rural areas and 11.4 per 1000 for urban areas and the corresponding infant mortality rates for rural and urban areas are 145 and 89 respectively. Almost every measure of mortality worked out confirms a higher mortality in rural areas. The mortality of females exceeds that of males except in the two ends of the age span. Especially the female mortality is significantly higher than male mortality in the reproductive age groups reflecting the effect of high maternal mortality rates prevalent in India.

A comparison of the proportionate distribution of deaths for India with those of Japan and Ceylon brings out the effect of differences in patterns of mortality associated with socio-economic conditions. Upto age 50 the proportions in India are higher than those in Japan and Ceylon reflecting the high infant and early childhood mortality and the mortality of women in the reproductive age groups. After age 50 the proportion of deaths is higher in Japan and Ceylon, especially marked by the case of Japan, due to the effect of aging of population.

NOTES

1 For detailed account of the SRS see Office of the Registrar General, India (Vital Statistics Division), *Sample Registration of Births and Deaths in India: Rural, 1965-1968*, New Delhi, 1970.

2 This is noted by other studies on India. See Kingsley Davis, *Population of India and Pakistan,* Princeton University Press, Princeton, 1951; P. K. Nambiar and K. E. Vaidyanathan, *Demography and Vital Statistics Report of Madras State,* Census of India, 1961 Vol. IX, Part I-B, Chapter on Mortality.

3 S. Chandrasekhar, *Infant Mortality in India,* London, Allen and Unwin, 1967.

Measurement of Mortality in Rural Gujarat Under Sample Registration

D. C. Mehta and M. H. Shah

Introduction

A fundamental problem facing nearly all public health administrators in developing countries is the general lack of routine, reliable, and current estimates of fertility and mortality. A glance through any one of the United Nations Yearbook clearly and dramatically demonstrates this fact.

An adequate civil registration system functioning throughout India would be the ideal method of keeping track of annual changes in fertility and mortality. Such a system, by collecting data on each vital event within hours or days after its occurrence, would eliminate errors in the data arising from faulty memory or from the failure to include babies who die shortly after birth. In India, however, the civil registration system is not functioning adequately; on the contrary, what evidence exists indicates a substantial under-registration of events in most states. Since the latest official publication of vital statistics from the civil registration system indicates death rates of less than 10 per 1000 population for many states[1], there is no evidence that civil registration has improved during the intervening period and it is most universally acknowledged that civil registration in India and in many states is generally poor[2].

It should be noted that the quality of the civil registration system is a general problem in most of the states in India, and the development of an adequate civil registration system tends to be a long-term effort. A national civil registration system is, by its very nature, a difficult thing to establish and maintain in any large country. It requires both that trained personnel be distributed

throughout the country and that such personnel function on a continuous basis. An effective civil registration system is, thus, more difficult to maintain than either a census (which is limited in time) or a sample survey (which is limited in area).

The enforcement of the Registration of Births and Deaths Act, 1969 from April 1, 1970 in most of the states (except few) appears to be a sound step towards the long-range development of civil registration system in India. However, in view of the difficulties discussed above, the usefulness of civil registration data in the measurement of fertility and mortality will remain limited in all the states of India for the next few decades.

Acknowledging the difficulties of obtaining meaningful and useable data from the civil registration system at an early date, the Registrar General's Office has undertaken the Sample Registration Scheme from 1965-66 in cooperation with the State Government[3]. Under the scheme, an appropriate organisation in each State Government (or, if a state government declines to participate, the State Office of the Census Organisation) carries the scheme work along the lines established by the Registrar General's Office ; in a probability urban/rural sample of the state. To date, pilot work has been completed in the rural and urban areas of all the states of India, and estimates based on twelve months of data from the full scale rural sample are available for most of the states [4]. In urban areas, however, only limited work on full scale has been carried out. It is expected that yearly estimates of births and deaths will be available for all the states urban and rural areas as well as for the state as a whole and for India from the calendar year 1971 and onwards.

This paper is mainly concerned with a brief description of the sample registration scheme as it operates in rural areas of Gujarat State with its results on mortality only for first two years. Detailed description and results of rural sample registration are published separately.[5]

Sample Registration in Rural Gujarat

The objective of the sample registration scheme is to record in the sampled areas births and deaths as they occur, as in civil

registration, so as to obtain reliable estimates of live birth and death rates for the State rural and urban areas. A pilot study on sample registration was taken up in Gujarat in the year 1964[6]. The object of the pilot was to study the practical problems involved in organising the sample registration scheme in rural and urban areas. The pilot survey was carried out in 20 rural and 5 urban non-random sample units.

The principal features of full scale rural sample registration in Gujarat is discussed below. Briefly, (1) a baseline survey of the sample unit is carried out to obtain a complete list of houses, households, and usual resident population. (2) There is continuous enumeration of vital events detected by the informant system, referred here as the "enumeration" method. (3) A retrospective survey of households is done every six months to detect independently births and deaths as well as migration and to provide the population base for the calculation of rates. (4) Enumeration and survey lists of vital events are matched, and unmatched and partially matched events are reverified.[7] Finally, estimates of events missed by both sources are prepared by the Chandrasekaran-Deming method.[8]

The full scale rural sample design, organisation of staff, and field work procedures for the Gujarat state programme are described below.

Sample Design

In the full scale sample registration scheme design, villages were stratified according to 1961 census population size groups, viz., under 500, 500-999, 1000-1999 and 2000 and over. Gujarat State was divided into three geographical regions—Ahmedabad, Rajkot, and Baroda, and 150 sample units were allocated randomly proportional to the population in each stratum within each region.

Later on, it was decided to implement Kaira Sample Registration Research Project. The Kaira Project is mainly concerned with testing new methods of sample registration. (The Kaira Project is sponsored by the National Centre for Health Statistics, Washington, and financed under PL 480 funds provided by the United States Govt.). Thus the 14 units which had been allocated to Kaira district in

Ahmedabad region were dropped, and a new sample design was developed for Kaira district. The district was divided into two parts. One is framed of two development blocks out of ten, viz., Anand and Nadiad, which were chosen to get "intensive" treatment with respect to both health and family planning services. The remaining eight blocks were to receive regular health and family planning services, the same as those provided in other parts of the state. Fifteen sample units were allocated to the "intensive" area; another 15 sample units were allocated to the remainder of Kaira proportional to the size of the population in each stratum. Moreover, villages in Kaira district having a population of 2000 or more were further subdivided into two strata. viz., 2000—4999 and 5000 and over.

The number of rural sampling units in Gujarat totalled 166, with Kaira district forming a separate fourth region. A total of 22 strata were identified for the state: ten strata were formed for Kaira district (five size groups by two types of area); twelve strata were formed for the rest of the state (four size groups by three regions). Thirty sample units were located in Kaira district, 136 in other regions of the state.

The sampling frame was prepared from data published in the 1961 district census hand books which showed villages by population size. The sampling unit for villages under 2000 population is a census village. For villages with a population of more than 2000, the sampling unit is a segment of the village. The number of segments assigned to these larger villages was determined by dividing the 1961 census population of the village by 2000 and rounding upto the next whole number. Sampling units were allocated in proportion to the population present in 1961, and the allocated number was randomly chosen from each stratum. For villages with a population of more than 2000, where a sampling unit was segment, a map of the village was prepared by the unit supervisor showing natural boundaries and approximate population. These maps were sent to the state office for identification of the sample segments.

Organisation

The sample registration unit at the state office is attached to the State Bureau of Health Intelligence under the State Directorate

of Health and Medical Services. The unit is composed of a statistical officer, four assistants and six full time supervisors. The work of the unit is supervised by a senior officer who is also responsible for implementing improvement in the vital statistics schemes of the Registrar General, India. The state unit is responsible for the overall direction and administration of the sample registration scheme.

Staff members appointed at the district level under the Registrar General's sponsored scheme of strengthening district vital statistics organisation are assigned responsibility for the supervision of all sample units in a district. Health staff appointed at the rural health centre, viz., sanitary inspector, vaccinator, family planning social and field worker, health visitor, midwife, etc., are assigned part time supervisory and survey responsibilities. One health worker is assigned to each sample unit for supervision and six month retrospective survey.

A local part time enumerator, usually a school teacher, is appointed in each village, and paid 15 to 25 rupees per month depending upon the size of the population in the village, to find, record, and report vital events to the state headquarters every month. Vital events are collected through informant system and the local enumerator is also responsible for the initial baseline survey and the numbering of houses for identification.

Field Work

Appointment of local part time enumerator and supervisor is done with the help of the district or primary health centre staff. Training sessions for the enumerators and supervisors are conducted at four regional levels by the statistical officer and the supervising officer for three days.

On return from training, the local enumerator is instructed to prepare a house list and conduct a survery showing the individuals in each household on a specified date. The local enumerator is also instructed to select local resident informants and to contact all the informants every fortnight. School children are also asked every week-end or on a fixed day, after prayer, the number of vital events known to them. In addition, the enumerator has to prepare a list of pregnant women in the sample unit and keep this list up-to-date.

Immediately at the end of one month, the local supervisor is instructed to visit the sample unit and to carry out initial inspection of enumerator's work and report his findings to the state headquarters. The local supervisor is also instructed to inspect the sample registration work whenever he visits the village in the course of his normal duties, atleast once every quarter.

On the date of the six-month retrospective household survey, the local enumerator is instructed to send the birth and death records to the district office. After a couple of days, the local supervisor (or full time supervisor from state office) is instructed to conduct the household survey independently and to bring the household register up-to-date. taking account of all changes in household composition -births, deaths and migration. The supervisor thus prepares a separate list of births and deaths which are mailed to the district office, where they are matched against the local enumerator's records. The local supervisor, in addition, tabulates data on population by age and sex as on the date of survey and sends the tabulation to the state headquarters.

The lists of partially matched and unmatched events are reverified in the field both by the enumerator and the supervisor. They are instructed to revisit the households concerned to determine, if possible, the real facts for each vital event in order to obtain and unduplicated list of the births and deaths.

Results on Mortality

On 1 October, 1967, the first and second years' experience with the rural sample registration scheme had been completed in Gujarat.

Measurement of Death Rate

Table 1 shows estimated (both Chandrasekaran-Deming and unbiased sampling method) death rates, by place of residence, for rural areas by region, stratum and for Gujarat State for 1965-66 and 1966-67 with standard error based on the unbiased sampling method.

Table 1

RESIDENT DEATH RATES PER 1000 MID-PERIOD POPULATION BY DIFFERENT METHODS WITH STANDARD ERROR BASED ON THE UNBIASED METHOD BY REGION, STRATUM AND PERIOD, SAMPLE REGISTRATION, RURAL, GUJARAT

Region/ Stratum	Period 1 October to 30 September	Resident death rate per 1000 population: Enumeration only	Survey only	Enumeration +survey	CD[a] method	Unbiased[b] method	SE[c]	CV[d]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Region								
Rajkot	1965-66	16.1	15.7	17.8	18.1	17.7	0.99	5.59
	1966-67	15.6	14.4	17.5	17.9	18.2	1.19	6.54
Ahmedabad	1965-66	16.2	17.6	19.1	19.4	19.1	1.25	6.54
	1966-67	19.3	19.8	22.2	22.6	22.5	1.38	6.13
Baroda	1965-66	15.6	16.6	18.0	18.3	17.8	0.89	5.00
	1966-67	14.5	15.5	17.8	18.4	17.8	0.79	4.44
Kaira	1965-66	18.7	18.5	21.1	21.4	20.2	1.37	6.78
	1966-67	18.1	18.8	21.8	22.5	22.5	1.40	6.22
Stratum								
Under 500	1965-66	14.4	16.6	17.5	17.8	17.3	1.98	11.45
	1966-67	17.5	17.5	20.0	20.5	19.1	1.85	9.69
500 – 999	1965-66	16.1	17.8	18.9	19.1	18.6	1.03	5.54
	1966-67	18.6	18.2	20.6	20.8	20.8	1.30	6.25
1000-1999	1965-66	17.0	16.8	18.8	19.0	18.5	0.91	4.92
	1966-67	17.2	17.2	19.8	20.3	19.5	0.91	4.67
2000 and over	1965-66	16.3	16.9	19.0	19.4	18.4	0.85	4.70
	1966-67	15.3	16.1	18.9	19.7	18.5	0.70	3.78
GUJARAT[e]	1965-66	16.5	17.0	18.8	19.1	18.3	0.55	3.01
	1966-67	16.6	16.9	19.6	20.1	19.5	0.58	2.97

[a] Estimated by Chandrasekaran-Deming method

[b] Estimated by Unbiased sampling method

[c] Standard error by unbiased method

[d] Coefficient of variation

[e] The civil registration death rates for rural Gujarat during 1966 and 1967 were 8.6 and 9.2 respectively per 1000 population.

Source : Annual Public Health Reports - Annual Form No. 6.

The estimated (unbiased sampling method) death rates are slightly higher in the second year than in the first year in all regions except Baroda and for all strata. The same is true for the estimated death rates in the state. It does appear that during the second year of the scheme, with more experience on the part of the staff, the work is somewhat better and more tightly controlled although there is evidence that considerably more supervision could be done.

The enumeration resident death rate has varied from 14.5 (1966-67) in Baroda region to 19.3 (1966-67) in Ahmedabad region while survey resident death rate has varied from 14.4 (1966-67) in Rajkot region to 19.8 (1966-67) in Ahmedabad region.

The combination of enumeration and survey method gives resident death rate per 1000 mid-period population for rural Gujarat as 18.8 for 1965-66 and 19.6 for 1966-67 respectively. The death rate so obtained by combination of enumeration and survey method, estimated by Chandrasekaran-Deming method and the unbiased method are statistically not significant at 95 per cent probability level for the last two years' experience. However, some of the death rates obtained by enumeration or survey only fall within the confidence limits. The rates indicate the amount of bias (underreporting) by either enumeration or survey. The amount of bias involved varies considerably by region and stratum. The shortfall in deaths for rural Gujarat was 18.3—17.0 = 1.3 for 1000 population by survey method.

The estimated death rate for rural Gujarat is 18.3 and 19.5 with 3.01 and 2.97 co-efficients of variation for the periods 1965-66 and 1966-67. This shows that the true death rate for rural Gujarat may lie in the range 17.2 to 19.4 for 1965-66 and 18.4 to 20.6 for 1966-67 with 95 per cent confidence limits.

The above mentioned unbiased estimate is worked out as recommended by the Third All-India Annual Conference on Sample Registration held at Calcutta, 3-7 March, 1967. In this method, estimate of deaths and population in each stratum within each region is obtained by using a mathematical scheme[9]. The region and state totals of deaths and population has been built up by adding the stratum values as independent sample was drawn in each stratum

within each region. Similarly, variances of death rates have been worked out. The estimation procedure includes deaths detected by enumeration and survey.

In general, it can be said that the standard errors are not large enough even by region and stratum to raise serious questions as to the validity of the conclusions to which the sample tabulations point. The detailed tabulations presented in this paper, should be regarded as indications of general orders of magnitude and not as precise estimates.

Completeness by Enumeration & Survey

The estimated percentage of recorded resident deaths by enumeration and survey methods is shown in Table 2 by region, stratum and period.

Table 2

ESTIMATED[a] PERCENTAGE COMPLETENESS OF DETECTION OF RESIDENT DEATHS BY ENUMERATION AND SURVEY, BY REGION, STRATUM AND PERIOD, SAMPLE REGISTRATION, RURAL, GUJARAT

Region/ stratum	Enumeration		Survey	
	1965-66	1966-67	1965-66	1966-67
(1)	(2)	(3)	(4)	(5)
GUJARAT	86.1	82.8	88.9	84.1
Region				
Rajkot	89.1	87.2	86.8	80.4
Ahmedabad	83.5	85.2	90.9	87.5
Baroda	85.4	78.7	90.9	84.5
Kaira	86.9	80.6	86.5	83.4
Stratum				
Under 500	81.2	85.6	93.5	85.6
500 - 999	84.7	89.2	93.6	87.4
1000 - 1999	89.6	84.7	88.6	84.4
2000 & over	84.2	77.9	87.0	82.2

[a]Estimated by Chandrasekaran - Deming method

By region, the percentage efficiency by the enumeration method varied from 78.7 (Baroda, 1966-67) to 89.1 (Rajkot, 1965-66) per cent while by stratum, it has varied from 77.9 (2000 & over, 1966-67) to 89.6 (1000-1999, 1965-66). For rural Gujarat, the under-enumeration by the enumeration method is estimated to be roughly of the order 14 to 17 per cent in the last two years. Similarly, by region, the percentage efficiency by the survey method varied from 80.4(Rajkot, 1966-67) to 90.9 (Ahmedabad and Baroda, 1965-66) per cent while by stratum it has varied from 82.2 (2000 & over, 1966-67) to 93.6 (500-999, 1965-66). For rural Gujarat, the under-enumeration by the survey method is estimated to be roughly of the order 11 to 16 per cent in the last two years.

Age-specific Death Rate

The age-specific death rates presented in Table 3 start at a rather high level in the first year of life, fall to a minimum near age ten, then move up slowly until mid-life, and finally rise rapidly at the older ages.

Table 3

RESIDENT AGE-SPECIFIC DEATH RATES BY SEX AND PERIOD, SAMPLE REGISTRATION, RURAL, GUJARAT

Age-group	Period	Age-specific death rates per 1000 population		
		Males	Females	Total
(1)	(2)	(3)	(4)	(5)
Under 1	1965-66	178.2	192.4	185.1
	1966-67	162.7	173.1	167.8
1-4	1965-66	29.4	42.7	35.9
	1966-67	35.3	46.0	40.5
5-14	1965-66	3.1	3.5	3.3
	1966-67	3.3	3.8	3.5
15-44	1965-66	3.7	5.1	4.4
	1966-67	3.8	5.7	4.7
45-64	1965-66	18.7	14.4	16.6
	1966-67	20.0	13.2	16.7
65-74	1965-66	84.5	60.5	72.2
	1966-67	65.0	70.7	68.0
75 +	1965-66	141.3	143.2	142.3
	1966-67	152.0	183.9	168.5

Table 3 also shows that the age-specific death rates for females are higher upto all age-groups under 44. There is also clear indication that mortality at the female reproductive ages is also high enough to raise the general death rate for females above the rate of males at the same ages.

Infant mortality experience

Infant mortality experience is rather difficult to analyse. However, analysis of data available under sample registration clearly indicates that infant mortality is much more higher in the areas and in the rural Gujarat than as recorded under civil registration. The infant mortality rate for rural Gujarat is 163 and 165 per 1000 live births during 1965-66 and 1966-67 respectively. Table 4 shows infant mortality rate by broad age-groups for 1965-66 and 1966-67.

Table 4

INFANT MORTALITY RATE BY AGE-GROUP AND PERIOD, SAMPLE REGISTRATION, RURAL, GUJARAT

Age group	Period	Infant mortality rate per 1000 live births
(1)	(2)	(3)
Under 1	1965-66	163
	1966-67	165
Under 7 days	1965-66	51
	1966-67	50
7 days—under 1 month	1965-66	29
	1966-67	24
1 month—11 months	1965-66	83
	1966-67	91

Seasonal mortality

Table 5 gives resident deaths with percentage to total deaths by month of occurrence for 1965-66 and 1966-67.

Table 5

RESIDENT DEATHS WITH PERCENTAGE TO TOTAL DEATHS BY MONTH OF OCCURRENCE AND PERIOD, SAMPLE REGISTRATION, RURAL, GUJARAT

Month	Period 1965-66 Number	Period 1965-66 Percentage	Period 1966-67 Number	Period 1966-67 Percentage
(1)	(2)	(3)	(4)	(5)
All months	3751	100.0	3934	100.0
October	336	9.0	285	7.2
November	321	8.6	278	7.1
December	306	8.2	282	7.2
January	301	8.0	340	8.6
February	279	7.4	298	7.6
March	293	7.8	382	9.7
April	267	7.1	295	7.5
May	287	7.7	337	8.6
June	285	7.6	277	7.0
July	312	8.3	351	8.9
August	381	10.1	408	10.4
September	383	10.2	401	10.2

There is a well-known seasonal cycle of deaths in the months of August and September i.e., during part of monsoon season.

Type of Medical Attention

Table 6 gives resident deaths with percentage by type of medical attention before death during 1965-66 and 1966-67 for rural Gujarat.

Table 6

RESIDENT DEATHS WITH PERCENTAGE BY TYPE OF MEDICAL ATTENTION BEFORE DEATH BY PERIOD, SAMPLE REGISTRATION, RURAL, GUJARAT

Period	All deaths	Institutional		Medical attention before death at home					
				By recognised practitioner		By unrecognised practitioner		None	
		No.	%	No.	%	No.	%	No.	%
(1)	(2)	(3)		(4)		(5)		(6)	
1965-66	3751	285	7.6	346	9.2	273	7.3	2847	75.9
1966-07	3934	362	9.2	311	7.9	357	9.1	2904	73.8

About 8 to 9 per cent of the deaths in rural Gujarat take place in medical institutions while approximately the same percentage of deaths are attended by recognised medical practitioners at home of the deceased. It is worthwhile to note that 74 to 76 per cent of the deaths get no medical attention before death.

Discussion

The experience obtained in the pilot study was used to increase the independence between enumeration and survey systems by withdrawing the enumerator's list before the survey began and matching work to be carried out at the district office. However, all points in the operation which can vitiate independence should be evaluated if independence is to be maintained in the sample registration.

A number of organisational and administration problems arose in conducting the pilot study and in expanding the sample registration operation. For example, the training of new staff mostly on transfer required much work on the part of the officers. House plates could not be fixed for identification in most of the sample units. The sub-division of larger villages into segments was

difficult, laborious, and time consuming because well drawn detailed village maps were not available. However, considerable progress is being made on these problems.

Detailed field work on matching including 'matching criterion' and 'number of items to be used for matching' have been developed by the Kaira Sample Registration Research Project.[10] Five items viz., House No. and Houshold No., name of deceased, sex of deceased, residential status, and date or month of death, were used for matching. If all the five items were matched on both the lists then the event is said to be matched, otherwise it is partially matched if some items do not match. The unmatched and partially matched events were reverified.

Summary and Conclusions

The Gujarat rural sample registration, initiated on full scale from 1 October, 1965, is a household enumeration instrument designed primarily to provide reliable and current data on vital rates. The sample size for rural Gujarat is about 200,000 persons.

Since October 1965, births and deaths in rural Gujarat State, India, have been recorded under two independent systems in a random sample of units. First, a part-time local "enumerator" is appointed in each sample unit (village or segment thereof) who prepares a house list; conducts a baseline survey showing the individuals in each household; and maintains a list of the vital events reported by informants whom he contacts fortnightly. Second, a staff member at the rural health centre is assigned part-time supervisory and to conduct a household survey each six months, updating the household register and recording births and deaths independently. The two lists are matched and all non-matches and partial matches are reverified.

The estimated death rate for rural Gujarat is 18.3 and 19.5 with 3.01 and 2.97 coefficients of variation for the periods 1965-66 and 1966-67. Thus, the true death rate for rural Gujarat may lie in the range 17.2 to 19.4 for 1965-66 and 18.4 to 20.6 for 1966-67 with 95 per cent confidence limits. Underenumeration for deaths

is estimated to be 14 to 17 per cent by the enumeration method, 11 to 16 per cent by the survey method in the last two years.

The age-specific death rates for females are higher upto all groups under 44. The infant mortality rate for rural Gujarat is 163 and 165 per 1000 live births during 1965-66 and 1966-67 respectively. More deaths have been recorded in the months of August and September. Only about 18 per cent of the deceased in the rural Gujarat got medical attention before death.

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The OSR Method for Estimating Mortality Levels from Age Distributions

K. V. Ramachandran and P. S. G. Nair

Introduction

In the so-called developing countries of the world, the lack of accurate or even acceptable vital statistics has made the problem of planning for social and economic development very difficult. Registration of vital events are either non-existent or are grossly deficient. Sample surveys have provided some information, but they have been of limited value. However, censuses have been taken in most of these countries in recent years, and some tabulations of age-sex distributions are available. Thus attempts have been made in the past and are still going on, under one assumption or the other, to utilise these age-sex tabulations to extract vital informations.[1]

The New Method

In this paper an attempt is made to provide a set of tables, using which one can estimate the level of mortality under certain elementary assumptions. These assumptions are generally valid and some of the assumptions may not be that important in their effect on the level of mortality estimation. One of the assumptions made is that the age-sex distributions are stable (or atleast nearabout so). Another assumption is that the population counts in broad age-sex groups are more or less complete in both the enumerations (or atleast that the errors in both the enumerations are similar). A third assumption is that a particular pattern of mortality operates and that this pattern holds good in all the age segments (in other words, the pattern assumed for the older cohorts apply as well for the births during a period). Under these assumptions, a set of tables have been prepared based on which one can estimate the level of mortality.

The method requires only the age-sex distribution of populations at a given interval which are available from censuses or surveys. But, since the age tabulations are subjected to errors of reporting, the method is based on a set of survival ratio of persons

of given ages enumerated in an earlier count to those of their survivors. Since cumulations may result in reduced amplitudes of errors, the method is based on survival ratios of persons of a given age and over to their corresponding numbers in a later count. Also, since there could be some amount of shifting of ages, several such survival ratios are calculated based on persons of consecutive ages. The theory underlying the new method, some details of its usefulness and a few illustrations of the application of the method were presented recently elsewhere.[2] This paper will confine itself to the set of tables needed for this new method.

The tables

A set of five tables each for the two sexes giving the overall survival ratios at five-year and ten-year intervals (in all 20 tables) are presented here (p. 74) which can be used profitably to estimate mortality level when the interval between the two enumerations are between 4 and 12 years. Tables M_1 to M_5 and F_1 to F_5 give respectively the survival ratios for males and females aged 0+, 5+, 10+, 15+ and 20+ at time 't' for a period of ten years. Tables M_6 to M_{10} and F_6 to F_{10} give respectively the survival ratios for males and females aged 0+, 5+, 10+, 15+ and 20+ at time 't' for a period of five years. These tables have been prepared from the Coale-Demeny model West life tables and corresponding stable populations.[3] Several initial rates of growth 'r' (r ranging from 0% to 3.5% per annum) of population are considered to enable the utilisation of the method in almost all circumstances expected to be met in practice. In case the rate of growth r in a given situation is not exactly equal to the tabulated value, linear interpolation may be used.

The value of 'E' given at the top of each table pertains to the initial level of expectation of life at birth and should be used in conjunction with knowledge about the approximate level of mortality in the country and its immediate course of development. When the period between two enumerations is not exactly five years the period can be converted into the required 5-10 year periods for the utilisation of these tables by projection of the population age structure of the earlier date or retrojection of the population age structure of the terminal date, provided the period is not too large.

NOTES

[1] Examples of such attempts are the United Nations Model Life Tables and Coale-Demeny Models. See United Nations, *Age and Sex Patterns of Mortality. Model Life Tables for Underdeveloped Countries,* New York 1955, Coale, A.J. and Paul Demeny, *Regional Model Life Table and Stable Populations,* Princeton, N. J. Princeton University Press, 1966.

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Table M. 1.

VALUES OF OVERALL SURVIVAL RATIOS $P^{t+10}_{10+} \,/\, P^{t}_{0+}$ FOR TEN-YEAR PERIODS FOR MALES CORRESPONDING TO BASE RATE OF GROWTH r, BASE EXPECTATION OF LIFE AT BIRTH E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD

e^0_0 During Period:	22.85	24.06	25.26	25.26	26.47	27.67	27.67	28.88	30 08
r	E=20.44			E=22.85			E=25.26		
0.0	.767	.775	.783	.777	.784	.791	.785	.792	.799
0.5	.778	.785	.794	.788	.795	.802	.797	.803	.810
1.0	.788	.795	.803	.798	.805	.812	.808	.814	.821
1.5	.796	.803	.811	.807	.813	.821	.817	.823	.870
2.0	.803	.810	.818	.815	.821	.828	.825	.831	.838
2.5	.809	.816	.824	.821	.827	.835	.832	.837	.844
3.0	.814	.821	.829	.827	.833	.840	.838	.843	.850
3.5	.819	.825	.833	.831	.837	.844	.843	.848	.855

e^0_0 During Period:	30.08	31.28	32.48	32.48	33.69	34.89	34.89	36.10	57.30
r	E=27.67			E=30.08			E=32.48		
0.0	.793	.799	.806	.800	.806	.812	.806	.812	.818
0.5	.805	.811	.818	.813	.818	.825	.818	.825	.831
1.0	.816	.823	.829	.824	.830	.836	.831	.837	.842
1.5	.826	.832	.838	.834	.840	.845	.842	.847	.853
2.0	.834	.840	.846	.843	.848	.854	.851	.856	.862
2.5	.842	.847	.854	.851	.856	.862	.859	.864	.870
3.0	.848	.853	.859	.857	.862	.868	.866	.871	.876
3.5	.854	.858	.865	.863	.868	.873	.872	.876	.882

Table M. 1 (Contd)

e_0^0 During Period:	37.50	38.51	39.71	39.71	40.92	42.12	42.12	43.32	44.52
r	E=34.89			E=37.30			E=39.71		
0.0	.812	.817	.823	.817	.822	.828	.823	.828	.833
0.5	.826	.832	.837	.832	.837	.843	.837	.843	.848
1.0	.839	.844	.849	.844	.849	.855	.851	.855	.860
1.5	.849	.854	.859	.855	.860	.866	.862	.867	.872
2.0	.859	.864	.869	.865	.870	.876	.873	.877	.882
2.5	.867	.872	.877	.874	.878	.884	.881	.886	.890
3.0	.874	.879	.884	.881	.885	.891	.889	.893	.897
3.5	.880	.884	.889	.887	.891	.897	.895	.899	.904

e_0^0 During Period:	44.52	45.82	47.11	47.11	48.34	49.56	49.56	50.70	51.83
r	E=42.12			E=44.52			E=47.11		
0.0	.827	.832	.837	.832	.837	.841	.836	.840	.844
0.5	.843	.848	.853	.848	.853	.857	.852	.856	.860
1.0	.857	.861	.866	.862	.866	.870	.866	.870	.874
1.5	.868	.873	.878	.874	.878	.882	.879	.883	.887
2.0	.879	.883	.888	.885	.889	.893	.890	.894	.898
2.5	.888	.892	.896	.894	.898	.902	.900	.903	.907
3.0	.896	.900	.904	.901	.905	.909	.908	.911	.915
3.5	.902	.906	.910	.909	.912	.917	.915	.918	.922

e_0^0 During Period:	51.83	52.99	54.14	54.14	55.31	56.47	56.47	57.66	58.84
r	E=49.56			E=51.83			E=54.14		
0.0	.840	.844	.848	.843	.848	.852	.847	8.51	.853
0.5	.856	.860	.864	.860	.864	.868	.864	.868	.872
1.0	.871	.875	.878	.875	.879	.883	.879	.883	.887
1.5	.884	.887	.891	.889	.892	.896	.893	.897	.900
2.0	.895	.899	.902	.900	.904	.907	.905	.908	.912
2.5	.905	.908	.912	.910	.914	.917	.915	.918	.922
3.0	.914	.917	.920	.918	.922	.925	.924	.927	.930
3.5	.921	.924	.927	.925	.928	.932	.931	.934	.938

Table M. 1 (Contd)

e_0^0 During Period:	58.84	60.04	61.23	61.23	62.44	63.64	63.64	64.83	66.02
r	E=56.47			E=58.84			E=61.23		
0.0	.851	.855	.859	.854	.858	.862	.858	.862	.865
0.5	.868	.873	.876	.872	.876	.880	.876	.879	.883
1.0	.884	.888	.801	.888	.892	.895	.892	.896	.899
1.5	.897	.901	.905	.902	.906	.909	.906	.909	.913
2.0	.909	.913	.917	.914	.917	.921	.918	.921	.925
2.5	.920	.923	.926	.925	.928	.931	.929	.932	.935
3.0	.929	.932	.935	.934	.937	.940	.938	.941	.944
3.5	.937	.939	.943	.941	.914	.947	.946	.949	.951

e_0^0 During Period:	66.02	67.29	68.56	68.56	69.88	71.19	71.19	72.55	73.90
r	E=63.64			E=66.02			E=68.56		
0.0	.861	.866	.870	.866	.872	.876	.870	.877	.882
0.5	.879	.884	.888	.884	.889	.894	.889	.895	.900
1.0	.896	.900	.904	.900	.905	.910	.905	.911	.915
1.5	.910	.914	.918	.915	.919	.933	.920	.925	.929
2.0	.922	.926	.930	.927	.932	.935	.932	.937	.940
2.5	.933	.937	.940	.938	.942	.945	.943	.947	.950
3.0	.943	.946	.949	.947	.951	.954	.952	.956	.959
3.5	.950	.953	.956	.955	.958	.961	.959	.963	.966

Table M. 2

VALUES OF $P^{t+10}_{15+} / P^{t}_{5+}$ i. e. OVERALL SURVIVAL RATIOS FOR TEN-YEAR PERIODS CORRESPONDING TO BASE RATE OF GROWTH r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD FOR MALES AGED 5+

e^0_0 During Period:	22.85	24.06	25.26	25.26	26.47	27.67	27.67	28.88	30.08
r	E=20.44			E=22.85			E=25.26		
0.0	.764	.772	.779	.772	.780	.786	.779	.786	.793
0.5	.776	.784	.791	.785	.792	.798	.792	.799	.805
1.0	.788	.795	.802	.796	.803	.810	.804	.811	.817
1.5	.798	.805	.812	.807	.814	.820	.815	.822	.827
2.0	.807	.814	.821	.816	.823	.829	.825	.831	.837
2.5	.815	.825	.829	.825	.832	.837	.834	.840	.845
3.0	.823	.830	.836	.833	.839	.845	.842	.848	.853
3.5	.830	.837	.842	.839	.846	.851	.848	.854	.859

e^0_0 During Period:	30.08	31.28	32.48	32.48	33.69	34.89	34.89	36.10	37.30
r	E=27.67			E=30.08			E=32.48		
0.0	.786	.793	.799	.792	.799	.804	.798	.804	.810
0.5	.800	.806	.812	.806	.812	.818	.812	.818	.823
1.0	.812	.819	.824	.819	.825	.830	.825	.831	.836
1.5	.823	.829	.835	.830	.836	.840	.837	.842	.847
2.0	.833	.838	.844	.840	.846	.850	.847	.853	.857
2.5	.842	.847	.853	.849	.855	.860	.857	.862	.866
3.0	.850	.856	.860	.857	.863	.868	.865	.870	.874
3.5	.857	.863	.867	.865	.870	.874	.872	.877	.881

Table M. 2 (Contd)

e_0^0 During Period:	37.30	38.51	39.71	39.71	40.92	42.12	42.12	43.32	44.52
r	E=34.89			E=37.30			E=39.71		
0.0	.803	.809	.814	.809	.814	.819	.814	.819	.824
0.5	.818	.824	.829	.824	.829	.834	.829	.834	.839
1.0	.832	.837	.842	.837	.842	.847	.843	.848	.852
1.5	.843	.848	.853	.849	.854	.859	.855	.860	.864
2.0	.854	.859	.864	.860	.865	.869	.866	.871	.875
2.5	.864	.868	.873	.870	.875	.879	.876	.881	.884
3.0	.872	.877	.881	.878	.883	.887	.885	.889	.893
3.5	.879	.884	.888	.886	.890	.894	.892	.897	.900

e_0^0 During Period:	44.52	45.82	47.11	47.11	48.34	49.56	49.56	50.70	51.83
r	E=42.12			E=44.52			E=47.11		
0.0	.818	.823	.828	.822	.827	.831	.826	.830	.834
0.5	.834	.839	.843	.839	.843	.847	.842	.847	.850
1.0	.848	.853	.857	.853	.857	.861	.857	.861	.864
1.5	.860	.865	.870	.866	.870	.873	.870	.874	.877
2.0	.872	.876	.881	.877	.881	.885	.882	.886	.889
2.5	.881	.886	.890	.887	.892	.895	.892	.896	.899
3.0	.891	.895	.899	.895	.899	.902	.902	.905	.908
3.5	.898	.903	.906	.904	.909	.911	.909	.913	.916

e_0^0 During Period:	51.83	52.99	54.14	54.14	55.31	56.47	56.47	57.66	58.84
r	E=49.56			E=51.83			E=54.14		
0.0	.829	.834	.838	.833	.838	.842	.837	.841	.845
0.5	.846	.850	.853	.850	.854	.858	.854	.858	.862
1.0	.861	.865	.869	.865	.869	.873	.869	.873	.877
1.5	.874	.878	.881	.879	.883	.886	.883	.887	.890
2.0	.887	.890	.893	.891	.895	.898	.895	.899	.902
2.5	.897	.901	.903	.902	.906	.909	.906	.910	.913
3.0	.906	.910	.913	.911	.914	.917	.916	.919	.922
3.5	.914	.918	.921	.918	.922	.925	.924	.927	.930

Table M. 2 (Contd)

e_0^0 During Period:	58.84	60.04	61.23	61.23	62.44	63.64	63.64	64.83	66.02
r	E=56.47			E=58.84			E=61.23		
0.0	.841	.845	.849	.844	.848	.852	.847	.852	.855
0.5	.858	.862	.866	.861	.866	.869	.865	.869	.873
1.0	.874	.878	.881	.877	.881	.885	.882	.886	.889
1.5	.887	.891	.895	.892	.896	.899	.996	.900	.903
2.0	.900	.904	.907	.904	.908	.911	.908	.912	.915
2.5	.911	.914	.918	.915	.919	.922	,920	.923	.926
3.0	.920	.924	.927	.925	.928	.931	.929	.933	.935
3.5	.929	.932	.935	.933	.937	.939	.938	.941	.943

e_0^0 During Period:	66.02	67.29	68.56	68.56	69.88	71.19	71.19	72.55	73.90
r	E=63.64			E=66.02			E=68.56		
0.0	.851	.856	.861	.856	.862	.867	.861	.868	.874
0.5	.869	.874	.878	.874	.880	.885	.879	.886	.891
1.0	.885	.890	.894	.890	.895	.900	.895	.901	.906
1.5	.899	.904	.908	.905	.910	.914	.910	.916	.920
2.0	.912	.917	.920	.918	.922	.926	.923	.928	.932
2.5	.924	.928	.931	.929	.933	.937	.934	.939	.942
3.0	.934	.938	.941	.939	,943	.946	.944	.948	.951
3.5	.942	.945	.948	.947	.950	.954	.952	.956	.959

Table M. 3

VALUES OF $P^{t+10}_{20+} / P^{t}_{10+}$, i.e., OVERALL SURVIVAL RATIOS FOR TEN YEAR PERIODS CORRESPONDING TO BASE RATE OF GROWTH, r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD FOR MALES AGED 10+

e^0_0 During Period:	22.85	24.06	25.26	25.26	26.47	27.67	27.67	28.88	30.08
r	E=20.44			E=22.85			E=25.26		
0.0	.743	.752	.759	.752	.760	.767	.760	.768	.774
0.5	.754	.763	.770	.764	.772	.779	.772	.780	.786
1.0	.765	.774	.781	.775	.783	.789	.784	.791	.797
1.5	.775	.783	.790	.785	.793	.799	.794	.801	.808
2.0	.784	.792	.799	.794	.802	.808	.804	.811	.817
2.5	.792	.800	.807	.813	.810	.816	.812	.819	.825
3.0	.799	.807	.814	.810	.818	.824	.820	.827	.833
3.5	.806	.814	.820	.817	.824	.830	.827	.834	.839

e^0_0 During Period:	30.08	31.28	32.48	32.48	33.69	34.89	34.89	36.10	37.30
r	E=27.67			E=30.08			E=32.48		
0.0	.768	.775	.781	.774	.781	.787	.781	.787	.793
0.5	.781	.788	.794	.788	.794	.800	.795	.801	.806
1.0	.792	.799	.805	.800	.806	.812	.807	.813	.818
1.5	.803	.810	.816	.811	.817	.822	.818	.824	.830
2.0	.812	.819	.825	.821	.827	.832	.829	.835	.839
2.5	.821	.827	.833	.830	.836	.841	.838	.844	.849
3.0	.829	.836	.841	.838	.844	.849	.846	.852	.856
3.5	.837	.843	.848	.845	.851	.856	.853	.859	.863

Table M. 3 (Contd)

e_0^0 During Period:	37.30	38.51	39.71	39.71	40.92	42.12	42.12	43.32	44.52
r	E=34.89			E=37.30			E=39.71		
0.0	.787	.793	.798	.792	.798	.803	.798	.804	.809
0.5	.801	.807	.812	.807	.813	.818	813	.818	.823
1.0	.814	.820	.825	.820	.826	.831	.826	.832	.836
1.5	.825	.831	.836	.832	.838	.842	.838	.844	.848
2.0	.836	.842	.846	.843	.848	.853	.849	.855	.859
2.5	.846	.851	.856	.853	.858	.862	.859	.865	.868
3.0	.854	.859	.864	861	.866	.871	.868	.873	.877
3.5	.861	.866	.871	.868	.874	.878	.876	.881	.885

e_0^0 During Period:	44.52	45.82	47.11	47.11	48.34	49.56	49.56	50.70	51.83
r	E=42.12			E=44.52			E=47.11		
0.0	.803	.808	813	.808	.813	.817	.812	.816	.820
0.5	.818	.823	.828	.824	.828	.832	.828	.832	.836
1.0	.832	.838	.841	.837	.842	.846	.842	.846	.850
1.5	.844	.850	.854	.850	.854	.858	.853	.859	.863
2.0	.856	.861	.865	.862	.866	.870	.867	.871	.874
2.5	.865	.870	.874	.872	.876	.880	.877	.881	.886
3.0	.875	.880	.883	.879	.884	.887	.887	.890	.894
3.5	.882	.887	.891	.889	.893	.897	.894	.898	.901

e_0^0 During Period:	51.83	52.99	54.14	54.14	55.31	56.47	56.47	57.66	58.84
r	E=49.56			E=51.83			E=54.14		
0.0	.815	.820	.824	.820	.824	.828	.822	.828	.832
0.5	.831	.836	.839	.836	.840	.844	.840	.844	.848
1.0	.846	.851	.854	.851	.855	.859	.855	.860	.863
1.5	.859	.864	.867	.865	.869	.872	.869	.874	.877
2.0	.872	.876	.879	.877	.881	.884	.882	.885	.889
2.5	.883	.886	.889	.888	.892	.895	.892	.896	.900
3.0	.892	.896	.899	.897	.901	.904	.903	.906	.909
3.5	.900	.904	.907	.905	.908	.912	.911	.914	.918

Table M. 3 (Contd)

e_0^0 During Period:	58.84 60.04 61.23			61.23 62.44 63.64			63.64 64.83 66.02		
r	E=56.47			E=58.84			E=61.23		
0.0	.828	.832	.836	.831	.836	.840	.835	.840	.844
0.5	.845	.849	.853	.848	.853	.857	.853	.857	.861
1.0	.860	.864	.868	.864	.869	.872	.869	.873	.876
1.5	.874	.878	.882	.879	.885	.887	.883	.887	.890
2.0	.886	.891	.894	.891	.895	.899	.895	.899	.903
2.5	.898	.901	.905	.903	.906	.910	.907	.911	.914
3.0	.907	,912	.914	.913	.916	.919	.917	.921	.924
3.5	.916	.920	.923	.921	.925	.928	.926	.930	.933

e_0^0 During Period:	66.02 67.29 68.56			68.56 69.88 71.19			71.19 72.55 73.90		
r	E=63.64			E=66.02			E=68.56		
0.0	.839	.845	.849	.845	.851	.856	.850	.858	.864
0.5	.856	.862	.867	.862	.868	.874	.868	.875	.881
1.0	.873	.878	.882	.878	.884	.889	.884	.891	.896
1.5	.887	.892	.896	.893	.898	.903	.899	.905	.910
2.0	.900	.905	.909	.906	.911	.915	.912	.917	.922
2.5	.912	.916	.920	.917	.923	.927	.923	.929	.933
3.0	.922	.927	.930	.928	.932	.936	.934	.939	.942
3.5	.931	.933	.958	.936	.941	.944	.942	.947	.950

Table M. 4

VALUES OF $P^{t+10}_{25+} / P^{t}_{15+}$, i.e., OVERALL SURVIVAL RATIOS FOR TEN YEAR PERIOD CORRESPONDING TO BASE RATE OF GROWTH, r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD FOR MALES AGED 15+.

e^0_0 During Period:	22.85	24.06	25.26	25.26	26.47	27.67	27.67	28.88	30.08
r	E=20.44			E=22.85			E=25.26		
0.0	.719	.728	.736	.729	.737	.745	.738	.746	.753
0.5	.730	.739	.747	.740	.749	.756	.750	.758	.765
1.0	.740	.749	.757	.750	.759	.766	.760	.768	.775
1.5	.749	.758	.765	.760	.768	.776	.770	.778	.785
2.0	.757	.766	.774	.769	.777	.784	.779	.787	.794
2.5	.765	.774	.781	.777	.785	.792	.788	.795	.802
3.0	.772	.781	.788	.785	.792	.799	.795	.803	.809
3.5	.779	.787	.794	.791	.799	.805	.802	.809	.816

e^0_0 During Period:	30.08	31.28	32.48	32.48	33.69	34.89	34.89	36.10	37.30
r	E=27.61			E=30.08			E=32.48		
0.0	.746	.754	.761	.754	.761	.768	.761	.768	.774
0.5	.759	.766	.773	.767	.774	.780	.774	.781	.787
1.0	.770	.778	.783	.778	.785	.791	.786	.793	.799
1.5	.780	.787	.794	.789	.796	.801	.797	.804	.809
2.0	.789	.796	.803	.798	.805	.811	.807	.814	.819
2.5	.798	.805	.811	.807	.814	.820	.817	.823	.828
3.0	.806	.813	.818	.815	.822	.828	.824	.831	.836
3.5	.813	.820	.825	.822	.829	.835	.831	.837	.843

Table M. 4 (Contd)

e_0^0 During Period:	37.30	38.51	39.71	39.71	40.92	42.12	42.12	43.32	44.52
r	E=34.89			E=37.30			E=39.71		
0.0	.768	.774	.780	.774	.780	.786	.780	.786	.791
0.5	.781	.788	.793	.788	.794	.800	.794	.800	.805
1.0	.794	.800	.806	.801	.807	.812	.809	.813	.818
1.5	.805	.811	.816	.812	.818	.824	.819	.825	.830
2.0	.815	.822	.827	.823	.829	.834	.830	.836	.841
2.5	.825	.831	.836	.833	.838	.844	.840	.846	.850
3.0	.833	.839	.845	.841	.846	.852	.849	.854	.859
3.5	.841	.846	.851	.848	.854	.859	.857	.862	.867

e_0^0 During Period:	44.52	45.82	47.11	47.11	48.34	49.56	49.56	50.70	51.83
r	E=42.12			E=44.52			E=47.11		
0.0	.786	.791	.796	.791	.796	.801	.795	.800	.804
0.5	.800	.806	.811	.806	.812	.816	.811	.815	.819
1.0	.814	.820	.824	.819	.825	.829	.824	.829	.833
1.5	.826	.832	.836	.832	.837	.841	.837	.842	.846
2.0	.837	.842	.847	.844	.848	.853	.850	.854	.858
2.5	.847	.852	.857	.854	.859	.863	.860	.864	.868
3.0	.856	.862	.866	.861	.867	.870	.869	.874	.877
3.5	.864	.870	.873	.871	.876	.880	.878	.882	.885

e_0^0 During Period:	51.83	52.99	56.14	54.14	55.31	56.47	56.47	57.66	58.84
r	E=49.56			E=51.83			E=54.14		
0.0	.799	.804	.808	.804	.809	.813	.808	.813	.818
0.5	.813	.820	.823	.820	.824	.828	.824	.829	.833
1.0	.829	.834	.838	.834	.839	.843	.839	.844	.848
1.5	.842	.847	.851	.848	.852	.857	.853	.858	.862
2.0	.855	.859	.863	.860	.865	.868	.865	.870	.874
2.5	.866	.870	.873	.871	.876	.880	.876	.881	.884
3.0	.875	.879	.883	.880	.885	.888	.887	.891	.894
3.5	.883	.888	.892	.889	.893	.896	.895	.899	.904

Table M. 4 (Contd)

e_0^0 During Period:	58.84	60.04	61.23	61.23	62.44	63.64	63.64	64.83	66.02
r	E=56.47			E=58.84			E=61.23		
0.0	.813	.818	.822	.817	.821	.826	.821	.826	.830
0.5	.829	.834	.838	.833	.838	.842	.838	.843	.847
1.0	.844	.849	.853	.849	.854	.858	.854	.858	.862
1.5	.858	.863	.866	.864	.868	.872	.868	.873	.876
2.0	.871	.876	.879	.876	.880	.884	.880	.885	.889
2.5	.882	.886	.890	.888	.892	.896	.893	.897	.901
3.0	.892	.897	.900	.898	.902	.905	.903	.907	.911
3.5	.90	.905	.909	.907	.911	.915	.913	.916	.920

e_0^0 During Period:	66.02	67.29	68.56	68.56	69.88	71.19	71.19	72.55	73.90
r	E=63.64			E=66.02			E=68.56		
0.0	.825	.831	.836	.831	.839	.844	.837	.846	.852
0.5	.842	.848	.853	.849	.855	.861	.855	.863	.869
1.0	.859	.864	.869	.864	.871	.877	.871	.878	.884
1.5	.873	.878	.883	.879	.885	.890	.886	.893	.898
2.0	.886	.891	.896	.893	.898	.903	.899	.905	.910
2.5	.898	.903	.907	.904	.910	.915	.911	.917	.921
3.0	.908	.914	.918	.915	.920	.925	.921	.927	.931
3.5	.918	.922	.926	.924	.929	.933	.930	.936	.940

Table M. 5

VALUES OF $P^{t+10}_{30+} / P^{t}_{20+}$, i.e., OVERALL SURVIVAL RATIOS FOR TEN YEAR PERIOD CORRESPONDING TO BASE RATE OF GROWTH, r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD FOR MALES AGED 20+

e^0_0 During Period:	22.85	24.06	25.26	25.26	26.47	27.67	27.67	28.88	30.08
r	E=20.44			E=22.85			E=25.26		
0.0	.693	.703	.712	.704	.713	.721	.714	.723	.730
0.5	.703	.713	.722	.715	.724	.732	.725	.734	.741
1.0	.713	.725	.731	.725	.734	.742	.736	.744	.751
1.5	.722	.731	.740	.734	.743	.751	.745	.754	.761
2.0	.730	.740	.748	.742	.751	.759	.754	.762	.770
2.5	.737	.747	.755	.750	.759	.767	.762	.770	.777
3.0	.744	.754	.762	.758	.766	.774	.770	.778	.785
3.5	.751	.760	.768	.764	.773	.780	.776	.784	.791

e^0_0 During Period:	30.08	31.28	32.48	32.48	33.69	34.89	34.89	36.10	37.30
r	E=27.67			E=30.08			E=32.48		
0.0	.723	.731	.738	.731	.739	.746	.739	.746	.753
0.5	.735	.743	.750	.744	.751	.748	.752	.759	.765
1.0	.746	.754	.761	.755	.762	.769	.763	.770	.777
1.5	.755	.764	.771	.765	.773	.778	.774	.782	.787
2.0	.764	.772	.779	.774	.782	.788	.784	.791	.797
2.5	.773	.780	.788	.783	.791	.797	.794	.801	.806
3.0	.781	.789	.795	.791	.799	.805	.801	.808	.814
3.5	.789	.796	.802	.799	.806	.812	.808	.815	.821

Table M. 5 (Contd)

e^0_0 During Period:	37.30 38.51 39.71			39.71 40.92 42.12			42.12 43.32 44.52		
r	E=34.89			E=37.50			E=39.71		
0.0	.746	.754	.760	.754	.760	.766	.760	.766	.772
0.5	.759	.767	.772	.767	.774	.780	.772	.780	.786
1.0	.772	.779	.785	.779	.786	.791	.787	.793	.798
1.5	.782	.789	.795	.791	.797	.803	.798	.804	.810
2.0	.793	.800	.805	.801	.807	.813	.809	.815	.820
2.5	.803	.809	.815	.811	.817	.823	.819	.825	.830
3.0	.811	.817	.823	.819	.825	.831	.828	.834	.839
3.5	.819	.825	.830	.827	.833	.839	.836	.842	.847

e^0_0 During Period:	44.52 45.82 47.11			47.11 48.34 49.56			49.56 50.70 51.83		
r	E=42.12			E=44.52			E=47.11		
0.0	.766	.772	.778	.772	.777	.782	.777	.781	.786
0.5	.780	.786	.792	.787	.792	.797	.792	.797	.801
1.0	.794	.800	.804	.799	.805	.810	.805	.810	.814
1.5	.806	.812	.817	.812	.817	.822	.818	.823	.827
2.0	.817	.822	.828	.824	.829	.833	.830	.835	.839
2.5	.826	.832	.837	.834	.839	.844	.840	.845	.849
3.0	.836	.842	.840	.841	.849	.851	.850	.854	.859
3.5	.844	.850	.854	.852	.857	.861	.859	.863	.867

e^0_0 During Period:	51.83 52.99 54.14			54.14 55.31 56.47			56.47 57.66 58.84		
r	E=49.56			E=51.83			E=54.14		
0.0	.781	.786	.790	.786	.791	.796	.791	.796	.800
0.5	.796	.801	.805	801	.806	.810	.806	.811	.816
1.0	.810	.815	.820	.816	.821	.825	.821	.826	.830
1.5	.823	.828	.832	.829	.834	.838	.835	.840	.844
2.0	.836	.840	.844	.841	.846	.850	.847	.852	.856
2.5	.847	.851	.855	.853	.857	.861	.858	.863	.867
3.0	.856	.861	.865	.862	.866	.871	.869	.873	.877
3.5	.865	.870	.874	.870	.875	.879	.878	.882	.887

Table M. 5 (Contd)

e_0^0 During Period:	58.84	60.04	61.23	61.23	62.44	63.64	63.64	64.83	66.02
r	E=56.47			E=58.84			E=61.23		
0.0	.796	.801	.805	.800	.805	.810	.804	.809	.814
0.5	.812	.817	.821	.816	.821	.826	.821	.826	.831
1.0	.827	.831	.836	.832	.837	.841	.837	.842	.846
1.5	.840	.845	.849	.846	.851	.855	.851	.856	.859
2.0	.853	.858	.862	.858	.863	.867	.863	.868	.873
2.5	.864	.869	.873	.870	.875	.879	.876	.880	.885
3.0	.875	.880	.883	.881	.885	.889	.887	.891	.895
3.5	.884	.889	.893	.891	.895	.899	.897	.901	.904

e_0^0 During Peroid:	66.02	67.29	68.56	68.56	69.88	71.19	71.19	72.55	73.90
r	E=63.64			E=66.02			E=68.56		
0.0	.809	.815	.821	.816	.824	.829	.823	.831	.838
0.5	.826	.832	.838	.833	.840	.846	.840	.848	.855
1.0	.842	.848	.853	.848	.855	.862	.856	.863	.870
1.5	.856	.862	.867	.863	.870	.875	.871	.878	.884
2.0	.869	.875	.880	.877	.883	.888	.884	.891	.896
2.5	.881	.887	.891	.888	.895	.900	.895	.902	.907
3.0	.892	.898	.902	.899	.905	.910	.907	.914	.918
3.5	.902	.907	.911	.909	.915	.920	.916	.923	.927

Table M. 6.

VALUES OF $P_{5+}^{t+5} / P_{o+}^{t}$, i.e., OVERALL SURVIVAL RATIOS FOR FIVE YEAR PERIODS CORRESPONDING TO BASE RATE OF GROWTH r, BASE EXPECTATIONS OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD FOR MALE POPULATION AGED 0+.

e_0^0 During Period	20.44	22.85	22.85	25.26	25.26	27.67	27.67	30.08	30.08	32.48
r	E=18.03		E=20.44		E=22.85		E=25.26		E=27.67	
0.0	.865	.876	.873	.882	.879	.888	.885	.893	.890	.897
0.5	.870	.881	.878	.887	.885	.893	.891	.899	.896	.903
1.0	.874	.884	.882	.892	.889	.898	.896	.904	.902	.909
1.5	.877	.887	.886	.895	.895	.902	.900	.908	.906	.913
2.0	.879	.890	.889	.898	.896	.905	.903	.911	.909	.917
2.5	.881	.892	.891	.900	.899	.907	.906	.914	.913	.920
3.0	.883	.893	.892	.902	.901	.909	.908	.916	.915	.922
3.5	.883	.894	.894	.903	.902	.911	.910	.918	.917	.924

Table M. 6 (Contd)

e_0^0 During Period	32.48	34.89	34.89	37.30	37.30	39.71	39.71	42.12	42.12	44.52	44.52	47.11
r	E=30.08		E=32.48		E=34.89		E=37.30		E=39.71		E=42.12	
0.0	.894	.902	.898	.905	.902	.908	.905	.911	.908	.914	.911	.917
0.5	.901	.908	.905	.912	.909	.915	.912	.919	.916	.922	.919	.925
1.0	.905	.913	.911	.917	.915	.922	.919	.925	.923	.928	.927	.932
1.5	.911	.918	.916	.923	.921	.927	.924	.931	.929	.934	.932	.938
2.0	.915	.922	.921	.927	.925	.931	.929	.935	.934	.939	.937	.943
2.5	.918	.925	.924	.930	.929	.935	.933	.939	.938	.943	.942	.947
3.0	.921	.928	.927	.933	.932	.938	.936	.942	.941	.946	.945	.950
3.5	.924	.930	.929	.935	.934	.940	.939	.945	.944	.949	.948	.953

e_0^0 During Period	47.11	49.56	49.56	51.83	51.83	54.14	54.14	56.47	56.47	58.84	58.84	61.23
r	E=44.52		E=47.11		E=49.56		E=51.83		E=54.14		E=56.47	
0.0	.914	.919	.916	.921	.918	.923	.921	.926	.923	.927	.925	.930
0.5	.923	.928	.925	.929	.927	.932	.930	.934	.932	.936	.934	.939
1.0	.930	.934	.932	.937	.935	.939	.937	.942	.940	.944	.942	.947
1.5	.936	.940	.939	.943	.942	.945	.944	.949	.947	.951	.949	.953
2.0	.941	.946	.945	.949	.947	.951	.950	.954	.953	.957	.956	.959
2.5	.946	.950	.949	.953	.952	.956	.955	.959	.958	.962	.961	.965
3.0	.948	.953	.953	.957	.956	.960	.959	.963	.962	.966	.965	.969
3.5	.953	.957	.956	.960	.960	.963	.962	.966	.966	.969	.969	.972

Table M. 6 (Contd)

e_0^0 During Period	61.23	63.64	63.64	66.02	66.02	68.56	68.56	71.19	71.19	73.90
r	E=58.84		E=61.23		E=63.64		E=66.02		E=68.56	
0.0	.927	.931	.929	.933	.931	.936	.933	.939	.936	.942
0.5	.936	.941	.938	.943	.940	.945	.943	.949	.946	.952
1.0	.945	.949	.947	.951	.949	.954	.951	.957	.954	.960
1.5	.952	.956	.954	.958	.956	.961	.959	.963	.962	.967
2.0	.958	.962	.960	.964	.963	.967	.965	.970	.968	.972
2.5	.963	.967	.966	.969	.968	.972	.971	.975	.975	.977
3.0	.968	.971	.970	.974	.973	.976	.975	.979	.978	.981
3.5	.971	.975	.974	.977	.976	.980	.979	.982	.981	,984

Table M. 7

VALUES OF $P_{10+}^{t+5} / P_{5+}^{t}$ i.e. OVERALL SURVIVAL RATIOS FOR FIVE-YEAR PERIODS CORRESPONDING TO BASE RATE OF GROWTH r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD FOR MALE POPULATION AGED 5+

e_0^0 During Peroid:	20.44	22.85	22.85	25.26	25.26	27.67	27.67	30.08	30.08	32.48
r	E=18.03		E=20.44		E=22.85		E=25.26		E=27.67	
0.0	.875	.884	.880	.888	.884	.892	.888	.896	.892	.899
0.5	.882	.891	.887	.895	.891	.899	.895	.903	.900	.906
1.0	.888	.897	.893	.901	.898	.905	.902	.909	.906	.913
1.5	.894	.902	.899	.907	.904	.911	.908	.915	.912	.919
2.0	.899	.907	.904	.912	.909	.916	.913	.920	.917	.924
2.5	.903	.911	.909	.916	.914	.920	.918	.924	.922	.928
3.0	.908	.915	.913	.920	.918	.924	.923	.928	.927	.932
3.5	.911	.918	.917	.923	.923	.928	.926	.932	.931	.936

Table M. 7 (Contd)

e_0^0 During Period:	32.48	34.89	34.89	37.30	37.30	39.71	39.71	42.12	42.12	44.52	44.52	47.11
r	E=30.08		E=32.48		E=34.89		E=37.30		E=39.71		E=42.12	
0.0	.895	.902	.898	.905	.901	.907	.904	.909	.906	.912	.909	.914
0.5	.903	.909	.906	.912	.909	.915	.912	.918	.915	.920	.917	.922
1.0	.910	.916	.913	.919	.917	.922	.919	.925	.922	.927	.925	.931
1.5	.916	.921	.920	.925	.923	.928	.926	.931	.929	.934	.932	.937
2.0	.921	.927	.925	.930	.929	.934	.932	.937	.935	.939	.938	.942
2.5	.926	.932	.930	.935	.934	.939	.937	.942	.940	.944	.943	.947
3.0	.931	.936	.934	.939	.938	.943	.941	.946	.945	.949	.948	.951
3.5	.935	.939	.938	.943	.942	.946	.945	.950	.948	.952	.951	.955

e_0^0 During Period:	47.11	49.56	49.56	51.83	51.83	54.14	54.14	56.47	56.47	58.84	58.84	61.23
r	E=44.52		E=47.11		E=49.56		E=51.83		E=54.14		E=56.47	
0.0	.911	.916	.913	.917	.914	.919	.917	.921	.918	.923	.920	.925
0.5	.920	.925	.922	.926	.924	.928	.926	.930	.928	.932	.930	.934
1.0	.927	.932	.929	.934	.932	.936	.934	.938	.936	.940	.938	.942
1.5	.934	.938	.937	.941	.939	.942	.941	.945	.943	.947	.945	.949
2.0	.940	.945	.943	.947	.945	.949	.947	.951	.950	.953	.952	.956
2.5	.946	.950	.948	.952	.951	.954	.953	.957	.955	.959	.958	.961
3.0	.649	.952	.953	.957	.955	.959	.957	.961	.960	.964	.963	.966
3.5	.955	.958	.957	.960	.960	.963	.961	.964	.964	.968	.967	.970

Table M. 7 (Contd)

e_o^o During Period:	61.23	63.64	63.64	66.02	66.02	68.56	68.56	71.19	71.19	73.20
r	E=58.84		E=61.23		E=63.64		E=66.02		E=68.56	
0.0	.922	.927	.924	.928	.926	.931	.929	.935	.931	.938
0.5	.932	.936	.934	.938	.935	.941	.938	.944	.941	.947
1.0	.940	.944	.942	.946	.944	.949	.946	.952	.949	.956
1.5	.948	.952	.950	.953	.952	.956	.954	.959	.957	.963
2.0	.954	.958	.956	.960	.958	.962	.961	.965	.964	.968
2.5	.960	.963	.962	.965	.964	.968	.967	.971	.969	.973
3.0	.965	.968	.967	.970	.969	.973	.972	.975	.974	.978
3.5	.969	.972	.971	.974	.973	.976	.976	.979	.978	.984

Table M. 8

VALUES OF $P^{t+5}_{15+} / P^{t}_{10+}$ i.e. OVERALL SURVIVAL RATIOS FOR FIVE-YEAR PERIODS CORRESPONDING TO BASE RATE OF GROWTH r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD FOR MALE POPULATION AGED 10+

e^0_0 During Peroid:	20.44	22.85	22.85	25.26	25.26	27.67	27.67	30.08	30.08	32.48
r	E=18.03		E=20.44		E=22.85		E=25.26		E=27.67	
0.0	.864	.874	.869	.878	.874	.883	.878	.886	.882	.890
0.5	.871	.880	.876	.885	.881	.889	.886	.893	.890	.897
1.0	.877	.886	.882	.891	.887	.895	.892	.900	.897	.904
1.5	.882	.891	.888	.896	.893	.901	.898	.905	.903	.909
2.0	.887	.896	.893	.901	.898	.906	.903	.910	.908	.914
2.5	.892	.900	.898	.906	.903	.910	.908	.915	.913	.919
3.0	.896	.904	.902	.909	.908	.915	.913	.919	.917	.923
3.5	.900	.908	.906	.913	.911	.918	.916	.923	.921	.927

Table M. 8 (Contd)

e_0^0 During Period	32.48	34.89	34.89	37.30	37.30	39.71	39.71	42.12	42.12	44.52	44.52	47.11
r	E=30.08		E=32.48		E=34.89		E=37.30		E=39.71		E=42.12	
0.0	.886	.894	.889	.896	.892	.899	.895	.902	.898	.904	.901	.907
0.5	.893	.901	.897	.904	.900	.907	.904	.910	.907	.912	.909	.915
1.0	.900	.907	.904	.910	.908	.914	.911	.917	.914	.919	.917	.922
1.5	.906	.912	.911	.917	.914	.920	.918	.923	.921	.926	.924	.929
2.0	.912	.918	.916	.922	.920	.926	.923	.929	.927	.932	.930	.935
2.5	.917	.923	.921	.927	.925	.931	.929	.934	.932	.937	.935	.940
3.0	.922	.928	.925	.931	.930	.935	.933	.938	.937	.941	.940	.944
3.5	.926	.931	.930	.935	.933	.939	.937	.942	.941	.945	.944	.948

e_0^0 During Period:	47.11	49.56	49.56	51.83	51.83	54.14	54.14	56.47	56.47	58.84	58.84	61.23
r	E=44.52		E=47.11		E=49.56		E=51.83		E=54.14		E=56.47	
0.0	.903	.909	.905	.910	.907	.912	.910	.915	.912	.916	.914	.919
0.5	.913	.917	.914	.919	.916	.921	.919	.923	.921	.925	.923	.928
1.0	.920	.925	.922	.927	.925	.929	.927	.931	.929	.933	.931	.936
1.5	.927	.931	.929	.933	.932	.935	.934	.939	.937	.941	.939	.943
2.0	.933	.937	.936	.940	.938	.942	.941	.944	.943	.947	.946	.949
2.5	.939	.943	.941	.945	.944	.947	.946	.950	.949	.952	.951	.955
3.0	.944	.948	.946	.950	.949	.952	.951	.955	.954	.958	.957	.960
3.5	.948	.951	.950	.954	.953	.956	.954	.958	.958	.962	.961	.964

Table M. 8 (Contd)

e^0_o During Period:	61.23	63.64	63.64	66.02	66.02	68.56	68.56	71.19	71.19	73.90
r	E=58.84		E=61.23		E=63.64		E=66.02		E=68.56	
0.0	.916	.920	.918	.922	.920	.925	.923	.929	.926	.933
0.5	.925	.930	.927	.932	.929	.935	.932	.939	.935	.942
1.0	.934	.938	.936	.940	.938	.943	.941	.947	.944	.951
1.5	.941	.946	.944	.948	.946	.951	.948	.954	.952	.958
2.0	.948	.952	.950	.954	.952	.957	.956	.960	.958	.963
2.5	.954	.957	.956	.960	.958	.963	.961	.966	.964	.969
3.0	.959	.962	.961	.965	.964	.968	.966	.971	.969	.973
3.5	.963	.966	.966	.969	.968	.972	.971	.975	.973	.978

Table M. 9

VALUES OF $P^{t+5}_{20+} / P^{t}_{15+}$, i.e., OVERALL SURVIVAL RATIOS FOR FIVE YEAR PERIODS CORRESPONDING TO BASE RATE OF GROWTH r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD FOR MALE POPULATION AGED 15+

e^0_0 During Period	20.44	22.85	22.85	25.26	25.26	27.67	27.67	30.08	30.08	32.48
r	E=18.03		E=20.44		E=22.85		E=25.26		E=27.67	
0.0	.850	.860	.855	.866	.861	.870	.866	.875	.871	.879
0.5	.856	.866	.862	.872	.868	.877	.873	.881	.878	.886
1.0	.862	.872	.868	.878	.874	.883	.879	.888	.884	.892
1.5	.867	.877	.873	.883	.879	.888	.885	.895	.890	.898
2.0	.871	.881	.878	.887	.884	.893	.890	.898	.895	.902
2.5	.876	.885	.883	.892	.889	.897	.895	.902	.900	.907
3.0	.880	.889	.887	.895	.893	.901	.899	.906	.905	.911
3.5	.883	.892	.891	.899	.897	.905	.903	.910	.909	.915

Table M. 9 (Contd)

e_0^0 During Period:	32.48	34.89	34.89	37.30	37.30	39.71	39.71	42.12	44.12	44.52	44.52	47.11
r	E=30.08		E=32.48		E=34.89		E=37.30		E=39.71		E=42.12	
0.0	.875	.883	.878	.886	.882	.889	.886	.892	.889	.895	.892	.898
0.5	.882	.890	.886	.893	.890	.897	.894	.900	.897	.903	.900	.906
1.0	.889	.896	.893	.899	.897	.904	.900	.907	.904	.910	.908	.913
1.5	.894	.901	.899	.906	.903	.910	.901	.913	.911	.917	.915	.920
2.0	.900	.906	.905	.911	.909	.915	.913	.919	.917	.922	.921	.926
2.5	.905	.911	.910	.916	.914	.921	.918	.924	.922	.927	.925	.931
3.0	.910	.916	.914	.920	.919	.925	.923	.929	.927	.932	.931	.935
3.5	.914	.920	.918	.924	.923	.928	.927	.932	.931	.936	.935	.939

e_0^0 During Peroid:	47.11	49.56	49.56	51.83	51.83	54.14	54.14	56.47	56.47	58.84	58.84	61.23
r	E=44.52		E=47.11		E=49.56		E=51.83		E=54.14		E=56.47	
0.0	.894	.900	.897	.902	.899	.904	.902	.907	.904	.909	.906	.911
0.5	.904	.909	.905	.910	.908	.913	.910	.915	.913	.917	.915	.921
1.0	.910	.916	.913	.918	.916	.921	.918	.923	.921	.925	.924	.928
1.5	.917	.922	.920	.925	.923	.927	.926	.931	.929	.933	.931	.935
2.0	.924	.929	.927	.931	.930	.934	.932	.936	.935	.939	.938	.942
2.5	.929	.934	.932	.936	.935	.939	.938	.942	.941	.945	.944	.948
3.0	.932	.936	.937	.942	.940	.944	.943	.947	.946	.950	.949	.953
3.5	.939	.943	.941	.945	.945	.949	.946	.950	.950	.955	.954	.958

Table M. 9 (Contd)

e°_{o} During Period	61.23	63.64	63.64	66.02	66.02	68.56	68.56	71.19	71.19	73.90
r	E=58.84		E=61.23		E=63.64		E=66.02		E=68.56	
0.0	.908	.913	.910	.916	.913	.919	.916	.923	.919	.927
0.5	.918	.923	.920	.925	.922	.928	.926	.933	.929	.937
1.0	.926	.931	.928	.933	.931	.937	.934	.941	.937	.945
1.5	.934	.938	.936	.941	.938	.944	.942	.948	.945	.952
2.0	.940	.945	.942	.947	.945	.950	.949	.954	.952	.958
2.5	.946	.950	.949	.953	.951	.956	.955	.960	.958	.963
3.0	.952	.955	.954	.958	.957	.962	.960	.965	.963	.968
3.5	.956	.960	.959	.962	.962	.966	.965	.970	.968	.973

Table M. 10

VALUES OF $P^{t+5}_{25+} / P^{t}_{20+}$, i.e., OVERALL SURVIVAL RATIOS FOR FIVE YEAR PERIODS CORRESPONDING TO BASE RATE OF GROWTH, r, BASE EXPECTATION OF LIFE AT BIRTH, E, AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD FOR MALE POPULATION AGED 20+

e^0_0 During Period	20.44	22.85	22.85	25.26	25.26	27.67	27.67	30.08	30.08	32.48
r	E=18.03		E=20.44		E=22.85		E=25.26		E=27.67	
0.0	.834	.846	.841	.852	.847	.857	.853	.862	.858	.867
0.5	.840	.852	.847	.858	.853	.863	.859	.869	.865	.873
1.0	.846	.857	.853	.864	.859	.869	.866	.875	.871	.880
1.5	.851	.862	.858	.868	.865	.874	.871	.880	.876	.885
2.0	.855	.866	.863	.873	.870	.879	.876	.885	.881	.890
2.5	.859	.870	.868	.877	.874	.884	.881	.889	.887	.894
3.0	.863	.874	.871	.881	.879	.888	.885	.893	.892	.899
3.5	.867	.877	.875	.885	.882	.891	.889	.897	.895	.903

Table M. 10 (Contd)

e_0^0 During Period	32.48	34.89	34.89	37.30	37.30	39.71	39.71	42.12	42.12	44.52	44.52	47.11
r	E=30.08		E=32.48		E=34.89		E=37.30		E=39.71		E=42.12	
0.0	.862	.871	.867	.875	.871	.878	.875	.882	.878	.885	.882	.888
0.5	.869	.878	.874	.882	.878	.886	.883	.890	.886	.893	.889	.896
1.0	.876	.884	.881	.888	.886	.893	.889	.896	.894	.900	.898	.903
1.5	.882	.889	.887	.884	.891	.898	.896	.903	.900	.906	.904	,910
2.0	.887	.894	.893	.900	.897	.904	.902	.909	.906	.912	.910	.916
2.5	.892	.899	.898	.905	.905	.910	.907	.914	.911	.917	.915	.921
3.0	.897	.904	.902	.909	.907	.914	.912	.918	.917	.922	.921	.926
3.5	.901	.908	.906	.913	.911	.917	.915	.922	.921	.926	.924	.930

e_0^0 During Period:	47.11	49.56	49.56	51.83	51.83	54.14	54.14	56.47	56.47	58.84	58.84	61.23
r	E=44.52		E=47.11		E=49.56		E=51.83		E=54.14		E=56.47	
0.0	.884	.891	.887	.892	.889	.895	.892	.898	.895	.900	.898	.903
0.5	.894	.899	.896	.901	.898	.903	.901	.906	.903	.909	.907	.912
1.0	.900	.906	.903	.908	.906	.911	.909	.914	.912	.917	.915	.920
1.5	.907	.912	.910	.915	.913	.918	.917	.922	.920	.924	.922	.927
2.0	.913	.919	.917	.922	.920	.925	.923	.928	.926	.930	.929	.934
2.5	.919	.924	.922	.927	.926	.930	.929	.934	.932	.936	.935	.940
3.0	.921	.926	.927	.933	.931	.935	.933	.938	.937	.942	.941	.945
3.5	.929	.934	.932	.936	.936	.940	.937	.942	.942	.947	.945	.950

Table M. 10 (Contd)

e_0^0 During Period:	61.23	63.64	63.64	66.02	66.02	68.56	68.56	71.19	71.19	73.90
r	E=58.84		E=61.23		E=63.64		E=66.02		E=68.56	
0.0	.900	.905	.902	.908	.905	.911	.908	.916	.912	.921
0.5	.909	.914	.911	.917	.914	.921	.918	.925	.921	.930
1.0	.917	.925	.920	.925	.925	.929	.926	.953	.930	.938
1.5	.925	.930	.928	.932	.930	.936	.934	.940	.938	.945
2.0	.932	.937	.934	.939	.937	.943	.941	.947	.945	.951
2.5	.938	.942	.941	.946	.943	.949	.947	.953	.951	.957
3.0	.944	.948	.947	.951	.949	.955	.953	.959	.957	.962
3.5	.948	.952	.952	.955	.955	.959	.958	.964	.961	.967

Table F. 1

VALUES OF $P^{t+10}_{10+} \;/\; P^{t}_{0+}$ i.e. OVERALL SURVIVAL RATIOS FOR TEN-YEAR PERIODS CORRESPONDING TO BASE RATE OF GROWTH, r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD OF FEMALES AGED 0+

e^0_0 During Peroid:	25.0	26.25	27.5	27.5	28.75	30.0	30.0	31.25	32.5
r	E=22.5			E=25			E=27.5		
0.0	.775	.781	.789	.783	.790	.797	.791	.798	.805
0.5	.784	.791	.799	.794	.800	.808	.803	.809	.816
1.0	.792	.799	.808	.803	.810	.817	.813	.819	.826
1.5	.800	.807	.815	.811	.818	.825	.822	.828	.835
2.0	.807	.813	.822	.819	.825	.832	.829	.835	.842
2.5	.812	.819	.827	.825	.831	.838	.836	.841	.848
3.0	.817	.823	.831	.830	.835	.843	.841	.846	.854
3.5	.820	.826	.835	.834	.839	.847	.846	.851	.858

e^0_0 During Period:	32.5	33.75	35.0	35.0	36.25	37.5	37.5	38.75	40.0
r	E=30			E=32.5			E=35		
0.0	.799	.805	.812	.806	.812	.818	.812	.818	.824
0.5	.811	.817	.824	.819	.825	.830	.826	.831	.837
1.0	.822	.828	.834	.830	.836	.841	.838	.843	.849
1.5	.831	.837	.843	.840	.845	.852	.848	.853	.859
2.0	.839	.845	.851	.848	.854	.859	.857	.862	.867
2.5	.846	.852	.857	.856	.860	.866	.864	.869	.874
3.0	.852	.857	.863	.861	.866	.872	.871	.875	.881
3.5	.856	.861	.868	.867	.871	.877	.876	.880	.886

Table F. 1 (Contd)

e_0^o During Period:	40.0	41.25	42.5	42.5	43.75	45	45	46.25	47.5
r	E=37.5			E=40			E=42.5		
0.0	.818	.824	.829	.824	.829	.834	.829	.834	.839
0.5	.832	.837	.843	.838	.844	.848	.844	.749	.854
1.0	.844	.850	.855	.851	.856	.861	,857	.861	.867
1.5	.855	.860	.865	.862	.867	.872	.868	.873	.878
2.0	.864	.869	.874	.871	.876	.881	.878	.882	.888
2.5	.872	.877	.882	.880	.884	.889	.887	.891	.895
3.0	.879	.883	.888	.887	.891	.896	.894	.898	.902
3.5	.884	.889	.894	.892	.896	.901	.900	.904	.909

e_0^o During Period:	47.5	48.75	50	50.0	51.25	52.5	52.5	53.75	55.0
r	E=45			E=47.5			E=50		
0.0	.834	.839	.844	.838	.842	.846	.842	.846	.850
0.5	.849	.854	.858	.854	.858	.862	.858	.862	.866
1.0	.863	.867	.871	.868	.872	.876	.872	.876	.881
1.5	.874	.879	.883	.880	.884	.888	.885	.889	.892
2.0	.885	.889	.893	.891	.894	.899	.896	.900	.904
2.5	.894	.898	.902	.900	.903	.907	.905	.909	.913
3.0	.901	.904	.909	.907	.911	.915	.913	.917	.921
3.5	.906	.910	,915	.914	.917	.921	.920	.923	.927

e_0^o During Period	55.0	56.25	57.5	57.5	58.75	60.0	60.0	61.25	62.5
r	E=52.5			E=55			E=57.5		
0.0	.846	.850	.854	.850	.854	.858	.854	.858	.862
0.5	.862	.867	.870	.867	.871	.875	.871	.875	.879
1.0	.877	.881	.885	.882	.886	.890	.886	.890	.894
1.5	.890	.894	.898	.895	.899	.903	.900	.904	.908
2.0	.902	.905	.909	.907	.910	.914	.912	.915	.919
2.5	.911	.915	.919	.916	.920	.923	.922	.925	.929
3.0	.920	.923	.926	.925	.928	.932	.931	.934	.937
3.5	.926	.930	.934	.932	.935	.939	.937	.940	.944

Table F. 1 (Contd)

e_0^0 During Period:	62.5	63.75	65.0	65.0	66.25	67.5	67.5	68.75	70.0
r	E=60			E=62.5			E=65		
0.0	.857	.861	.865	.861	.865	.869	.864	.868	.872
0.5	.875	.879	.883	.879	.883	.887	.882	.886	.890
1.0	.891	.895	.898	.895	.898	.902	.899	.903	.906
1.5	.904	.908	.911	.909	.912	.916	.911	.913	.918
2.0	.917	.920	.923	.921	.924	.928	.925	.929	.932
2.5	.927	.930	.933	.931	.934	.938	.936	.939	.942
3.0	.936	.938	.942	.940	.943	.946	.945	.948	.951
3.5	.943	.946	.949	.948	.950	.954	.952	.956	.958

e_0^0 During Peroid:	70.0	71.25	72.5	72.5	73.75	75.0	75.0	76.25	77.5
r	E=67.5			E=70			E=72.5		
0.0	.867	.873	.877	.872	.878	.883	.876	.883	.887
0.5	.886	.891	.895	.890	.896	.900	.895	.901	.905
1.0	.902	.907	.911	.907	.912	.916	.911	.916	.920
1.5	.917	.921	.925	.922	.926	.929	.926	.930	.933
2.0	.930	.933	.937	.934	.938	.942	.938	.942	.945
2.5	.940	.943	.946	.944	.948	.951	.949	.952	.955
3.0	.949	.953	.956	.954	.957	.960	.958	.961	.963
3.5	.957	.960	.963	.961	.964	.966	.965	.968	.970

Table F. 2

VALUES OF $P^{t+10}_{15+} / P^{t}_{5+}$ i.e. OVERALL SURVIVAL RATIOS FOR TEN-YEAR PERIODS CORRESPONDING TO BASE RATE OF GROWTH, r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD OF FEMALES AGED 5+

e^0_0 During Period:	25.0	26.25	27.5	27.5	28.75	30.0	30.0	31.25	32.5
r	E=22.5			E=25			E=27.5		
0.0	.771	.779	.786	.779	.787	.793	.787	.794	.800
0.5	.783	.791	.798	.792	.799	.805	.800	.806	.812
1.0	.794	.801	.808	.803	.810	.816	.811	.818	.824
1.5	.804	.811	.818	.813	.820	.826	.822	.828	.834
2.0	.812	.819	.826	.822	.829	.835	.831	.837	.843
2.5	.820	.827	.833	.830	.836	.842	.839	.845	.851
3.0	.827	.834	.840	.837	.843	.849	.846	.852	.858
3.5	.833	.840	.846	.843	.849	.855	.853	.859	.864

e^0_0 During Period	32.5	33.75	35.0	35.0	36.25	37.5	37.5	58.75	40.0
r	E=30			E=32.5			E=36		
0.0	.794	.800	.806	.800	.806	.812	.806	.812	.817
0.5	.807	.813	.819	.813	.820	.825	.820	.823	.831
1.0	.819	.825	.831	.826	.832	.837	.833	.838	.843
1.5	.829	.836	.841	.837	.843	.848	.844	.849	.854
2.0	.839	.845	.850	.847	.853	.857	.854	.860	.864
2.5	.848	.854	.858	.856	.861	.866	.863	.868	.873
3.0	.855	.860	.865	.863	.868	.873	.871	.876	.880
3.5	.861	.867	.872	.870	.875	.880	.877	.882	.887

Table F. 2 (Contd)

e_0^0 During Period:	40.0	41.25	42.5	42.5	43.75	45.0	45.0	46.25	47.5
r	E=37.5			E=40			E=42.5		
0.0	.811	.817	.822	.816	.822	.826	.821	.826	.831
0.5	.826	.831	.836	.831	.837	.841	.836	.841	.846
1.0	.838	.844	.849	.844	.849	.854	.850	.855	.859
1.5	.851	.856	.860	.857	.862	.866	.862	.867	.871
2.0	.861	.866	.869	.867	.872	.876	.875	.878	.882
2.5	.870	.875	.880	.876	.881	.885	.882	.887	.891
3.0	.878	.882	.887	.885	.889	.893	.891	.895	.899
3.5	.885	.889	.893	.892	.896	.900	.898	.903	.906

e_0^0 During Period:	47.5	48.75	50 0	50.0	51.25	52.5	52.5	53.75	55.0
r	E=45			E=47.5			E=50		
0.0	.826	.831	.835	.829	.834	.837	.833	.837	.841
0.5	.841	.846	.850	.845	.850	.854	.849	.854	.857
1.0	.855	.860	.864	.860	.864	.867	.864	.868	.872
1.5	.868	.872	.876	.873	.877	.880	.877	.881	.884
2.0	.879	.883	.887	.884	.888	.891	.888	.893	.896
2.5	.889	.893	.897	.894	.898	.901	.899	.903	.906
3.0	.897	.901	.905	.902	.906	.909	.908	.912	.915
3.5	.904	.908	.911	.910	.914	.917	.915	.919	.922

e_0^0 During Period:	55.0	56.25	57.5	57.5	58.75	60.0	60.0	61.25	62.5
r	E=52.5			E=55			E=57.5		
0.0	.837	.841	.845	.841	.845	.849	.844	.849	.853
0.5	.853	.858	.861	.858	.862	.866	.862	.866	.869
1.0	.868	.872	.877	.875	.877	.880	.877	.881	.884
1.5	.882	.886	.889	.887	.891	.894	.891	.895	.899
2.0	.894	.898	.901	.899	.902	.906	.903	.907	.910
2.5	.904	.908	.911	.909	.913	.916	.914	.918	.921
3.0	.913	.917	.920	.918	.922	.925	.923	.927	.930
3.5	.921	.925	.928	.926	.929	.932	.931	.934	.937

Table F. 2 (Contd)

e_0^0 During Period:	62.5	63.75	65.0	65.0	66.25	67.5	67.5	68.75	70.0
r	E=60			E=62.5			E=65		
0.0	.848	.852	.856	.851	.856	.859	.855	.859	.863
0.5	.865	.870	.873	.869	.873	.878	.872	.877	.880
1.0	.881	.885	.889	.885	.889	.892	.889	.893	.896
1.5	.895	.899	.902	.899	.903	.907	.902	.905	.909
2.0	.908	.912	.915	.912	.916	.919	.916	.920	.923
2.5	.918	.922	.925	.923	.926	.929	.927	.931	.934
3.0	.920	.931	.934	.932	.936	.939	.937	.941	.944
3.5	.936	.939	.942	.940	.943	.946	.945	.949	.951

e_0^0 During Period:	70.0	71.25	72.5	72.5	73.75	75.0	75.0	76.25	77.5
r	E=67.5			E=70			E=72.5		
0.0	.858	.864	.868	.863	.870	.874	.867	.874	.879
0.5	.877	.882	.886	.881	.887	.891	.886	.892	.897
1.0	.893	.898	.902	.898	.903	.907	.902	.908	.912
1.5	.908	.912	.916	.913	.917	.921	.917	.922	.926
2.0	.921	.925	.928	.925	.930	.934	.930	.935	.938
2.5	.931	.935	.938	.936	.940	.944	.941	.945	.948
3.0	.941	.945	.948	.946	.949	.953	.950	.954	.957
3.5	.950	.953	.956	.954	.957	.960	.958	.962	.964

Table F. 3

VALUES OF $P_{20+}^{t+10} \,/\, P_{10+}^{t}$ OVERALL SURVIVAL RATIOS FOR TEN-YEAR PERIOD CORRESPONDING TO BASE RATE OF GROWTH, r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD OF FEMALES AGED 10+

e_0^0 During Period:	25.0	26.25	27.5	27.5	28.75	30.0	30.0	31.25	32.5
r		E=22.5			E=25			E=27.5	
0.0	.754	.762	.769	.762	.7 0	.777	.770	.778	.784
0.5	.765	.773	.780	.774	.782	.789	.783	.790	.796
1.0	.775	.783	.790	.785	.793	.799	.794	.801	.807
1.5	.785	.793	.800	.795	.802	.809	.804	.811	.817
2.0	.793	.801	.808	.804	.811	.817	.813	.820	.826
2.5	.801	.809	.815	.812	.819	.825	.822	.828	.834
3.0	.808	.815	.822	.819	.826	.832	.829	.835	.841
3.5	.814	.821	.828	.825	.832	.838	.835	.842.	.847

e_0^0 During Period	32.5	33.75	35.0	35.0	36.25	37.5	37.5	38.75	40.0
r		E=30			E=32.5			E=35	
0.0	.778	.785	.791	.784	.791	.797	.790	.797	.802
0.5	.790	.797	.803	.798	.804	.810	.804	.810	.816
1.0	.802	.809	.815	.810	.816	.821	.817	.823	.828
1.5	.813	.820	.825	.820	.827	.833	.826	.834	.839
2.0	.822	.829	.834	.830	.837	.842	.838	.844	.849
2.5	.831	.837	.842	.839	.845	.850	.847	.853	.857
3.0	.838	.844	.850	.846	.852	.857	.856	.860	.866
3.5	.845	851	.856	.854	.860	.864	.862	.867	.872

Table F. 3 (Contd)

e_0^0 During Period:	40.0	41.25	42.5	42.5	43.75	45.0	45.0	46.25	47.5
r	E=37.5			E=40			E=42.5		
0.0	.796	.802	.808	.802	.808	.812	.807	.813	.817
0.5	.811	.816	.822	.817	.822	.827	.822	.828	.832
1.0	.823	.829	.834	.830	.835	.840	.836	.840	.845
1.5	.835	.841	.846	.842	.847	.851	.848	.853	.857
2.0	.845	.851	.855	.852	.857	.862	.858	.863	.868
2.5	.855	.860	.865	.862	.867	.871	.868	.873	.877
3.0	.863	.868	.872	.870	.873	.879	.877	.882	.885
3.5	.870	.875	.879	.877	.882	.886	.884	.889	.893

e_0^0 During Period:	47.5	48.75	50.0	50.0	51.25	52.5	52.5	53.75	55.0
r	E=45			E=47.5			E=50		
0.0	.812	.818	.822	.816	.821	.825	.820	.825	.828
0.5	.827	.832	.837	.832	.837	.840	.836	.840	.844
1.0	.841	.846	.850	.846	.850	.854	.850	.855	.859
1.5	.853	.859	.862	.859	.863	.867	.863	.867	.871
2.0	.865	.869	.874	.870	.874	.876	.875	.879	.883
2.5	.875	.880	.883	.881	.885	.888	.885	.890	.893
3.0	.884	.889	.892	.889	.893	.896	.895	.899	.903
3.5	.890	.895	.899	.897	.901	.904	.902	.906	.910

e_0^0 During Period:	55.0	56.25	57.5	57.5	58.75	60.0	60.0	61.25	62.5
r	E=52.5			E=55			E=57.5		
0.0	.824	.829	.833	.828	.833	.837	.832	.837	.841
0.5	.840	.845	.848	.845	.849	.853	.849	.853	.857
1.0	.855	.859	.864	.860	.864	.868	.864	.869	.872
1.5	.869	.873	.877	.874	.878	.881	.879	.883	.887
2.0	.861	.885	.888	.886	.890	.894	.891	.895	.898
2.5	.892	.895	.899	.896	.900	.903	.901	.906	.909
3.0	.901	.905	.908	.906	.910	.913	.911	.915	.918
3.5	.909	.913	.916	.914	.917	.921	.923	.923	.926

Table F. 3 (Contd)

e_0^0 During Period:	62.5	63.75	65.0	65.0	66.25	67.5	67.5	68.75	70.0
r	E=60			E=62.5			E=65		
0.0	.836	.840	.844	.839	.844	.848	.843	.848	.852
0.5	.853	.858	.861	.857	.862	.866	.861	.865	.869
1.0	.869	.873	.877	.873	.877	.881	.877	.882	.885
1.5	.883	,887	.890	.887	.891	.895	.890	.894	.898
2.0	.895	.900	.903	.900	.904	.908	.905	.909	.918
2.5	.906	.910	.914	.911	.915	.918	.916	.920	.923
3.0	.916	.920	.923	.921	,925	.928	.926	.930	.935
3.5	.925	.928	.931	.929	.933	,936	.935	.939	.942

e_0^0 During Peroid:	70.0	71.25	72.5	72.5	73.75	75.0	75.0	76.25	77.5
r	E=67.5			E=70			E=72.5		
0.0	.847	.853	.858	.853	.860	.864	.857	.865	.870
0.5	.865	.871	.875	.870	.876	.881	.876	.882	.888
1.0	.881	.887	.891	.887	.893	.897	.892	.898	.903
1.5	.896	.901	.905	.902	.907	.911	.907	.912	.916
2.0	.910	.914	.918	.915	.920	.924	.920	.925	.929
2.5	.921	.925	.928	.926	.931	.934	.931	.935	.939
3.0	.931	.936	.939	.936	.940	.944	.941	.945	.949
3.5	.940	.943	.947	.945	.949	.951	.950	.954	.957

Table F. 4

VALUES OF $P^{t+10}_{25+} / P^{t}_{15+}$ OVERALL SURVIVAL RATIOS FOR TEN-YEAR PERIOD CORRESPONDING TO BASE RATE OF GROWTH, r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD OF FEMALES AGED 15+

e^o_0 During Period:	25	26.25	27.5	27.5	28.75	30.0	30.0	31.25	32.5
r	E=22.5			E=25			E=27.5		
0.0	.734	.743	.750	.743	.751	.758	.751	.759	.766
0.5	.745	.753	.761	.754	.763	.770	.763	.771	.778
1.0	.754	.763	.771	.765	.773	.780	.775	.782	.789
1.5	.764	.772	.780	.774	.782	.789	.784	.792	.798
2.0	.772	.780	.788	.783	.791	.798	.793	.801	.807
2.5	.779	.788	.795	.791	.799	.805	.802	.809	.815
3.0	.786	.794	.801	.798	.806	.812	.809	.816	.822
3.5	.792	.800	.807	.804	.812	.818	.815	.822	.828

e^o_0 During Period:	32.5	33.75	35.0	35.0	36.25	37.5	37.5	38.75	40.0
r	E=30			E=32.5			E=35		
0.0	.760	.767	.773	.767	.774	.780	.773	.780	.786
0.5	.772	.779	.785	.780	.787	.792	.787	.793	.799
1.0	.783	.791	.797	.792	.798	.804	.799	.805	.811
1.5	.794	.801	.807	.802	.809	.815	.810	.816	.822
2.0	.803	.810	.815	.812	.819	.824	.820	.827	.832
2.5	.812	.819	.824	.821	.827	.833	.829	.835	.840
3.0	.819	.826	.831	.828	.834	.840	.837	.843	.849
3.5	.826	.832	.838	.836	.842	.847	.844	.850	.856

Table F. 4 (Contd)

e_0^0 During Period	40.0	41.25	42.5	42.5	43.75	45.0	45.0	46.25	47.5
r	E=37.5			E=40			E=42.5		
0.0	.780	.786	.792	.786	.792	.797	.791	.797	.802
0.5	.794	.800	.805	.800	.806	.811	.806	.812	.817
1.0	.806	.812	.817	.813	.818	.824	.819	.824	.830
1.5	.818	.824	.829	.825	.830	.835	.831	.836	.841
2.0	.828	.834	.838	.835	.841	.845	.842	.847	.852
2.5	.837	.843	.848	.845	.850	.855	.852	.857	.861
3.0	.846	.851	.856	.853	.859	.863	.861	.866	.870
3.5	.853	.858	.863	.861	.866	.871	.869	.874	.878

e_0^0 During Period	47.5	48.75	50.0	50.0	51.25	52.5	52.5	53.75	55.0
r	E=45			E=47.5			E=50		
0.0	.797	.803	.807	.801	.806	.810	.805	.810	.814
0.5	.812	.817	.822	.817	.821	.825	.821	.825	.829
1.0	.823	.831	.834	.830	.835	.839	.835	.839	.844
1.5	.837	.843	.847	.845	.848	.851	.848	.852	.856
2.0	.849	.854	.858	.854	.859	.863	.859	.864	.868
2.5	.859	.864	.868	.865	.869	.873	.870	.874	.878
3.0	.868	.872	.877	.873	.878	.881	.880	.884	.888
3.5	.875	.880	.884	.882	.887	.890	.887	.892	.896

e_0^0 During Period:	55.0	56.25	57.5	57.5	58.75	60.0	60	61.25	62.5
r	E=52.5			E=55			E=57.5		
0.0	.810	.814	.818	.814	.819	.823	.818	.823	.827
0.5	.825	.830	.834	.830	.835	.839	.835	.839	.843
1.0	.840	.844	.849	.845	.849	.854	.850	.854	.858
1.5	.853	.858	.862	.859	.863	.867	.864	.869	.873
2.0	.865	.870	.874	.871	.875	.879	.876	.880	.884
2.5	.877	.880	.884	.882	.886	.889	.887	.892	.896
3.0	.886	.890	.894	.892	.896	.899	.898	.901	.905
3.5	.894	.899	.902	.900	.904	.908	.906	.910	.913

Table F. 4 (Contd)

e_0^0 During Period:	62.5	63.75	65.0	65.0	66.25	67.5	67.5	68.75	70.0
r	E=60			E=62.5			E=65		
0.0	.822	.827	.831	.826	.831	.835	.830	.835	.839
0.5	.839	.844	.848	.843	.848	.853	.847	.852	.856
1.0	.855	.859	.863	.859	.864	.868	.863	.869	.872
1.5	.869	.873	.817	.873	.878	.882	.876	.880	.884
2.0	.881	.886	.889	.886	.891	.895	.891	.896	.900
2.5	.892	.897	.901	.897	.902	.905	.903	.907	.911
3.0	.903	.907	.910	.908	.912	.915	.914	.918	.921
3.5	.911	.915	.919	.917	.920	.924	.922	.927	.930

e_0^0 During Period:	70.0	71.25	72.5	72.5	73.75	75.0	75.0	76.25	77.5
r	E=67.5			E=70			E=72.5		
0.0	.834	.841	.846	.841	.848	.853	.846	.853	.859
0.5	.852	.858	.863	.858	.864	.870	.864	.871	.877
1.0	.868	.874	.878	.874	.881	.885	.880	.887	.892
1.5	.883	.888	.893	.889	.895	.899	.895	.901	.905
2.0	.896	.902	.906	.903	.908	.912	.908	.914	.918
2.5	.908	.913	.917	.914	.919	.923	.920	.925	.929
3.0	.918	.924	.927	.924	.929	.933	.930	.935	.939
3.5	.928	.932	.936	.934	.938	.941	.939	.944	.948

Table F 5

VALUES OF $P^{t+10}_{30+} \;/\; P^{t}_{20+}$ OVERALL SURVIVAL RATIOS FOR TEN-YEAR PERIODS CORRESPONDING TO BASE RATE OF GROWTH, r, BASE EXPECTATION OF LIFE AT BIRTH E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD OF FEMALES AGED 20+

e^0_0 During Period:	25	26.25	27.5	27.5	28.75	30.0	30.0	31.25	32.5
r	E=22.5			E=25			E=27.5		
0.0	.712	.722	.730	.722	.731	.738	.731	.740	.747
0.5	.723	.732	.740	.733	.742	.749	.743	.751	.758
1.0	.733	.742	.750	,744	.752	.759	.754	.762	.769
1.5	.742	.751	.759	.753	.761	.769	.764	.771	.778
2.0	.750	.759	.766	.762	.770	.777	.773	.780	.787
2.5	.757	.766	.774	.770	.778	.785	.781	.788	.795
3.0	.764	.773	.780	.777	.785	.792	.788	.796	.802
3.5	.770	.779	.786	.783	.791	.798	.795	.802	.809

e^0_0 During Period:	32.5	33.75	35.0	35.0	36.25	37.5	37.5	38.75	40.0
r	E=30			E=32.5			E=35		
0.0	.740	.748	.754	.748	.755	.761	.755	.762	.767
0.5	.752	.759	.766	.760	.768	.773	.767	.774	.780
1.0	.763	.771	.777	.772	.779	.785	.780	.786	.792
1.5	.773	.781	.787	.782	.790	.796	.791	.797	803
2.0	.782	.790	.796	.792	.799	.805	.801	.808	.814
2.5	.791	.799	.804	.801	.808	.814	.809	.816	.822
3.0	.798	.806	.812	.808	.815	.820	.818	.824	.830
3.5	.806	.812	.819	.816	.823	.829	.825	.832	.838

Table F. 5 (Contd)

e_0^0 During Peroid:	40.0	41.25	42.5	42.5	43.75	45.0	45.0	46.25	47.5
r	E=37.5			E=40			E=42.5		
0.0	.761	.768	.774	.767	.774	.779	.774	.780	.785
0.5	.775	.781	.787	.732	.788	.793	.788	.794	.799
1.0	.787	.794	.799	.794	.800	.806	.801	.806	.812
1.5	.799	.805	.811	.806	.812	.817	.813	.818	.823
2.0	.809	.815	.819	.845	.822	.827	.824	.829	.835
2.5	.819	.825	.830	.826	.832	.837	.834	.839	.844
3.0	.827	.833	.838	.835	.841	.846	.843	.848	.853
3.5	.834	.840	.845	.843	.849	.854	.851	.857	.861

e_0^0 During Period:	47.5	48.75	50.0	50.0	51.25	52 5	52.5	53.75	55.0
r	E=45			E=47.5			E=50		
0.0	.779	.785	.790	.784	.789	.793	.788	.794	.798
0.5	.794	.800	.804	.799	.804	.808	.804	.808	.813
1.0	.807	.813	.817	.813	.818	.822	.818	.822	.827
1.5	.819	.825	.830	.826	.830	.834	.830	.833	.839
2.0	.831	.836	.841	.837	.842	.846	.842	.847	.851
2.5	.841	.847	.851	.848	.852	.856	.853	.858	.862
3.0	.851	.855	.860	.856	.861	.865	.863	.868	.872
3.5	.858	.863	.867	.866	.870	.874	.871	.876	.879

e_0^0 During Period	55.0	56.25	57.5	57.5	58.75	60.0	60.0	61.25	62.5
r	E=52.5			E=55			E=57.5		
0.0	.793	.798	.802	.798	.803	.807	.802	.808	.812
0.5	.808	.814	.817	.814	.818	.823	.818	.823	.827
1.0	.823	.828	.832	.828	.833	.837	.833	.838	.842
1.5	.836	.841	.845	.842	.847	.850	.847	.852	.857
2.0	.848	.853	.857	.854	.859	.863	.860	.864	.868
2.5	.859	.864	.868	.865	.870	.873	.871	.876	.880
3.0	.869	.874	.878	.875	.880	.883	.881	.886	.889
3.5	.878	.883	.887	.884	.888	.892	.890	.894	.899

Table F. 5 (Contd)

e_0^0 During Period:	62.5	63.75	65.0	65.0	66.25	67.5	67.5	68.75	70.0
r	E=60			E=62.5			E=65		
0.0	.806	.812	.816	.811	.816	.820	.815	.820	.825
0.5	.823	.828	.832	.828	.833	.838	.832	.837	.841
1.0	.838	.843	.847	.843	.848	.852	.848	.853	.857
1.5	.852	.857	.861	.857	.862	.866	.860	.864	.869
2.0	.865	.869	.873	.870	.875	.879	.875	.880	.884
2.5	.876	.881	.885	.882	.886	.890	.888	.892	.896
3.0	.887	.891	.895	.893	.897	.901	.899	.903	.907
3.5	.896	.900	.904	.902	.905	.910	.908	.913	.916

e_0^0 During Period:	70.0	71.25	72.5	72.5	73.75	75.0	75.0	76.25	77.5
r	E=67.5			E=70			E=72.5		
0.0	.820	.826	.832	.826	.834	.840	.832	.840	.847
0.5	.837	.843	.848	.843	.850	.856	.850	.858	.864
1.0	.853	.859	.864	.860	.866	.872	.866	.873	.879
1.5	.867	.873	.878	.874	.881	.885	.880	.887	.892
2.0	.881	.887	.891	.888	.894	.899	.894	.901	.905
2.5	.893	.898	.902	.899	.905	.910	.906	.911	.916
3.0	.903	.910	.914	.910	.916	.921	.917	.922	.927
3.5	.914	.918	.923	.920	.925	.929	.926	.932	.936

Table F. 6

VALUES OF $P_{5+}^{t+5} / P_{0+}^{t}$, i.e., OVERALL SURVIVAL RATIOS FOR FIVE YEAR PERIODS CORRESPONDING TO BASE RATE OF GROWTH, r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD FOR FEMALE POPULATION AGED 0+

e_0^0 During Period:	22.5	25.0	25.0	27.5	27.5	30.0	30.0	32.5	32.5	35.0
r	E=20		E=22.5		E=25		E=27.5		E=30	
0.0	.869	.879	.876	.886	.882	.891	.888	.896	.893	.901
0.5	.873	.883	.881	.890	.888	.896	.894	.902	.899	.906
1.0	.876	.887	.885	.894	.892	.901	.899	.906	.904	.912
1.5	.879	.890	.888	.897	.896	.904	.902	.910	.909	.916
2.0	.881	.892	.890	.900	.899	.907	.906	.913	.912	.919
2.5	.883	.893	.892	.902	.901	.909	.908	.916	.915	.922
3.0	.884	.894	.894	.903	.902	.911	.910	.918	.917	.924
3.5	.884	.895	.895	.904	.904	.912	.912	.919	.919	.926

Table F. 6 (Contd)

e_0^0 During Peroid:	35.0	37.5	37.5	40.0	40.0	42.5	42.5	45.0	45.0	47.5	47.5	50.0
r	E=32.5		E=35		E=37.5		E=40		E=42.5		E=45	
0.0	.897	.905	.902	.908	.905	.912	.908	.914	.912	.917	.915	.920
0.5	.904	.911	.908	.915	.912	.918	.916	.922	.919	.925	.923	.928
1.0	.909	.916	.914	.921	.918	.924	.922	.928	.926	.932	.930	.935
1.5	.914	.921	.919	.925	.924	.930	.928	.934	.932	.937	.935	.940
2.0	.918	.924	.923	.930	.928	.934	.932	.938	.936	.942	.940	.945
2.5	.921	.928	.927	.933	.932	.938	.936	.941	.940	.945	.945	.949
3.0	.923	.930	.929	.935	.934	.940	.939	.945	.944	.949	.948	.953
3.5	.926	.932	.931	.938	.937	.942	.942	.947	.946	.951	.950	.955

e_0^0 During Period	50.0	52.5	52.5	55.0	55.0	57.5	57.5	60.0	60.0	62.5	62.5	65.0
r	E=47.5		E=50		E=52.5		E=55		E=57.5		E=60	
0.0	.917	.922	.919	.924	.922	.927	.924	.929	.926	.931	.928	.933
0.5	.925	.930	.928	.933	.930	.935	.933	.937	.935	.940	.938	.942
1.0	.935	.937	.935	.940	.938	.943	.941	.945	.943	.948	.946	.950
1.5	.939	.943	.942	.946	.945	.949	.948	.952	.951	.955	.953	.957
2.0	.944	.949	.947	.951	.950	.955	.954	.958	.956	.960	.959	.963
2.5	.948	.953	.952	.956	.955	.959	.958	.962	.961	.966	.964	.968
3.0	.952	.956	.956	.960	.959	.963	.963	.966	.966	.969	.969	.972
3.5	.955	.959	.958	.963	.962	.967	.966	.970	.969	.972	.972	.975

Table F 6 (Contd)

e_0^0 During Period	65.0	67.5	67.5	70.0	70.0	72.5	72.5	75.0	75.0	77.5
r	E=62.5		E=65		E=67.5		E=70		E=72.5	
0.0	.930	.935	.932	.937	.934	.940	.937	.943	.939	.945
0.5	.940	.945	.942	.946	.944	.949	.946	.951	.949	.954
1.0	.948	.952	.950	.954	.952	.957	.955	.960	.957	.962
1.5	.955	.959	.956	.960	.960	.964	.962	.966	.964	.968
2.0	.962	.965	.964	.968	.966	.970	.969	.973	.971	.974
2.5	.966	.970	.969	.973	.971	.975	.974	.977	.976	.979
3.0	.971	.975	.974	.977	.976	.979	.978	.982	.980	.983
3.5	.975	.978	.977	.980	.980	.983	.982	.985	.984	.987

Table F. 7

VALUES OF $P_{10+}^{t+5} \,/\, P_{5+}^{t}$, i.e., OVERALL SURVIVAL RATIOS FOR FIVE-YEAR PERIODS CORRESPONDING TO BASE RATE OF GROWTH, r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD FOR FEMALE POPULATION AGED 5+

e_0^0 During Period:	22.5	25.0	25.0	27.5	27.5	30.0	30.0	32.5	32.5	35.0
r	E=20		E=22.5		E=25		E=27.5		E=30	
0.0	.878	.887	.883	.892	.887	.895	.892	.898	.895	.903
0.5	.885	.894	.890	.898	.895	.902	.899	.906	.903	.909
1.0	.891	.899	.896	.904	.901	.908	.905	.912	.909	.916
1.5	.896	.904	.901	.909	.906	.913	.911	.917	.915	.922
2.0	.901	.908	.906	.913	.911	.918	.916	.922	.920	.926
2.5	.905	.912	.910	.917	.916	.922	.920	.927	.925	.930
3.0	.908	.916	.914	.821	.919	.926	.924	.930	.929	.934
3.5	.911	.919	.917	.924	.923	.929	.928	.933	.932	.938

Table F. 7 (Contd)

e_0^0 During Period	35.0	37.5	37.5	40.0	40.0	42.5	42.5	45.0	45.0	47.5	47.5	50.0
r	E=32.5		E=35		E=37.5		E=40		E=42.5		E=45	
0.0	.899	.905	.902	.503	.904	.911	.907	.913	.910	.915	.913	.918
0.5	.906	.912	.909	.916	.913	.918	.916	.921	.918	.924	.921	.926
1.0	.913	.919	.017	.922	.920	.925	.923	.928	.926	.931	.928	.933
1.5	.919	.926	·923	.928	.926	.932	.929	.935	.932	.937	.935	.939
2.0	.924	.930	.928	.934	.932	.936	.935	.940	.938	.943	.941	.945
2.5	.929	.934	.935	.938	.937	.942	.940	.944	.943	.947	.946	.950
3.0	.932	.938	.937	.942	.941	.945	.944	.949	.947	.951	.951	.954
3.5	937	.942	.940	.946	.944	.949	·948	.952	.951	.955	.954	.958

e_0^0 During Period:	50.0	52.5	52.5	55.0	55.0	57.5	57.5	60.C0	60.0	62.5	62.5	65.0
r	E=47.5		E=50		E=52.5		E=55		E=57.5		E=60	
0.0	.914	.919	.916	.921	.918	.923	,921	.925	.922	.927	.924	.928
0.5	.923	.928	.925	.930	.927	.931	.930	.934	.932	.936	.933	.938
1.0	.931	.935	.933	.937	.935	.940	.937	.942	.939	.944	.942	.946
1.5	.938	.942	.940	.944	.942	.946	,945	.949	.947	.951	.949	.953
2.0	.944	.948	.946	.950	.949	.952	.951	.955	.954	.957	.956	.960
2.5	.949	.952	.951	.955	.954	.958	.956	.960	.959	.963	.961	.963
3.0	.953	.956	.956	.960	.959	.962	.961	.965	.964	.967	.966	.969
3.5	.957	.961	.960	.963	.963	.966	.963	.968	.968	.971	.970	.973

Table F. 7 (Contd)

e_0^0 During Period:	65.0	67.5	67.5	70.0	70.0	72.5	72.5	75.0	75.0	77.5
r	E=62.5		E=65		E=67.5		E=70		E=72.5	
0.0	.926	.930	.928	.932	.929	.935	.932	.938	.934	.941
0.5	.935	.940	.937	.941	.939	.944	.942	.947	.944	.950
1.0	.944	.948	,946	.950	.948	.952	.950	.956	.953	.958
1.5	.951	.955	.951	.955	.956	.960	.958	.962	.960	.965
2.0	.958	.962	.960	.964	.962	.966	.965	.969	.967	.971
2.5	.963	.967	.966	.969	.968	.971	.970	.974	.972	.976
3.0	.968	.971	.971	.974	.973	.976	.975	.978	.977	.980
3.5	.972	.975	.975	.977	.977	.980	.979	.982	.981	.984

Table F. 8

VALUES OF $P_{15+}^{t+5} / P_{10+}^{t}$, i.e., OVERALL SURVIVAL RATIOS FOR FIVE YEAR PERIODS CORRESPONDING TO BASE RATE OF GROWTH, r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD FOR FEMALE POPULATION AGED 10+

e_0^0 During Peroid:	22.5	25.0	25.0	27.5	27.5	30.0	30.0	32.5	32.5	35.0
r	E=20		E=22.5		E=25		E=27.5		E=30	
0.0	.869	.879	.874	.883	.879	.887	.883	.891	.887	895
0.5	.875	.885	.881	.890	.886	.894	.890	.898	.894	.901
1.0	.881	.890	.887	.895	.892	.900	.897	.904	.901	.908
1.5	.886	.895	.892	.900	.897	.905	.902	.909	.907	.914
2.0	.891	.900	.897	.905	.902	.910	.907	.914	.912	.918
2.5	.895	.903	.901	.909	.907	.914	.912	.919	.917	.923
3.0	.899	.907	.905	.912	.911	.918	.916	.922	.921	.927
3.5	.902	.910	.908	.916	.914	.921	.919	.926	.934	.930

Table F. 8 (Contd)

e_0^0 During Period:	35.0	37.5	37.5	40.0	40.0	42.5	42.5	45.0	45.0	47.5	47.5	50.0
r	E=32.5		E=35		E=37.5		E=40		E=42.5		E=45	
0.0	.891	.898	.894	.901	.897	.904	.900	.906	.903	.909	.906	.911
0.5	.898	.905	.901	.908	.905	.911	.909	.914	.911	.917	.914	.919
1.0	.905	.911	.909	.915	.912	.918	.915	.921	.918	.924	.922	.926
1.5	.911	.918	.915	.921	.919	.925	.922	.928	.925	.930	.928	.933
2.0	.916	.922	.921	.927	.924	.929	.927	.933	.931	.936	.934	.939
2.5	.922	.927	.925	.931	.929	.935	.933	.938	.936	.941	.940	.944
3.0	.925	.931	.930	.935	.933	.938	.937	.942	.941	.945	.944	.948
3.5	.929	.935	.933	.939	.937	.942	.941	.946	.945	.949	.947	.952

e_0^0 During Period:	50.0	52.5	52.5	55.0	55.0	57.5	57.5	60.0	60.0	62.5	62.5	65.0
r	E=47.5		E=50		E=52.5		E=55		E=57.5		E=60	
0.0	.908	.912	.909	.914	.912	.917	.914	.919	.916	.921	.918	.923
0.5	.916	.921	.918	.923	.921	.925	.923	.927	.925	.930	.927	.932
1.0	.924	.928	.926	.931	.929	.933	.931	.935	.933	.938	.936	.940
1.5	.931	.935	.933	.937	.936	.940	.939	.943	.941	.946	.943	.947
2.0	.937	.941	.939	.944	.942	.946	.945	.949	.948	.952	.950	.954
2.5	.943	.946	.945	.949	.948	.952	.950	.954	.953	.957	.956	.959
3.0	.947	.950	.950	.954	.953	.957	.956	.959	.958	.962	.961	.964
3.5	.951	.955	.954	.957	.957	.961	.959	.963	.962	.966	.965	.968

Table F. 8 (Contd)

e_0^0 During Period:	65.0	67.5	67.5	70.0	70.0	72.5	72.5	75.0	75.0	77.5
r	E=62.5		E=65		E=67.5		E=70		E=72.5	
0.0	.920	.925	.922	.927	.924	.930	.927	.934	.929	.936
0.5	.930	.935	.931	.936	.934	.939	.936	.942	.939	.946
1.0	.938	.942	.940	.944	.942	.947	.945	.951	.948	.954
1.5	.945	.950	.945	.950	.950	.955	.953	.958	.955	.960
2.0	.952	.956	.954	.958	.957	.962	.960	.965	.962	.967
2.5	.957	.961	.961	.964	.963	.967	.965	.969	.967	.972
3.0	.963	.967	.966	.969	.968	.973	.970	.975	.973	.977
3.5	.967	.971	.970	.973	.972	.976	.975	.978	.977	.981

Table F. 9

VALUES OF $P_{20+}^{t+5} \,/\, P_{15+}^{t}$ i.e., OVERALL SURVIVAL RATIOS FOR FIVE-YEAR PERIODS CORRESPONDING TO BASE RATE OF GROWTH r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD OF FEMALES AGED 15+

e_0^0 During Period	22.5	25.0	25.0	27.5	27.5	30.0	30.0	32.5	32.5	35.0
r	E=20		E=22.5		E=25		E=27.5		E=30	
0.0	.857	.867	.863	.873	.868	.877	.873	.881	.877	.886
0.5	.863	.873	.869	.879	.875	.883	.880	.888	.884	.892
1.0	.869	.879	.875	.884	.881	.889	.886	.894	.891	.898
1.5	.874	.883	.880	.889	.886	.894	.891	.899	.897	.904
2.0	.878	.888	.885	.894	.891	.899	.897	.904	.901	.909
2.5	.882	.892	.889	.898	.895	.903	.901	.909	.907	.913
3.0	.886	.895	.893	.901	.899	.907	.905	.912	.911	.917
3.5	.889	.898	.896	.904	.903	.910	.909	.916	.914	.921

Table M. 9 (Contd)

e_0^0 During Period	35.0	37.5	37.5	40.0	40.0	42.5	42.5	45.0	45.0	47.5	47.5	50.0
r	E=32.5		E=35		E=37.5		E=40		E=42.5		E=45	
0.0	.881	.889	.885	.892	.838	.895	.891	.898	.895	.901	.898	.903
0.5	.889	.896	.892	.899	.896	.902	.900	.905	.903	.909	.906	.911
1.0	.895	.902	.899	.906	.903	.909	.906	.913	.910	.916	.913	.918
1.5	.901	.909	.905	.912	.910	.916	.913	.919	.917	.922	.920	.925
2.0	.907	.913	.911	.918	.915	.921	.919	.925	.922	.928	.926	.931
2.5	.912	.918	.916	.922	.920	.926	.924	.929	.927	.933	.931	.936
3.0	.915	.921	.920	.926	.925	.930	.929	.934	.932	.937	.936	.941
3.5	.920	.926	.924	.930	.928	.934	.932	.937	.937	.941	.939	.944

e_0^0 During Period:	50.0	.52.5	52.5	55.0	55.0	57.5	57.5	60.0	60.0	62.5	62.5	.65.0
r	E=47.5		E=50		E=52.5		E=55		E=57.5		E=60	
0.0	.900	.905	.902	.907	.905	.909	.907	.912	.909	.914	.911	.916
0.5	.908	.913	.911	.916	.913	.918	.916	.920	.918	.923	.921	.925
1.0	.916	.921	.918	.923	.921	.926	.923	.928	.926	.931	.929	.933
1.5	.923	.927	.925	.930	.928	.933	.931	.936	.934	.939	.936	.940
2.0	.929	.933	.931	.936	.935	.939	.938	.942	.940	.945	.943	.947
2.5	.935	.939	.937	.942	.940	.945	.945	.947	.946	.951	.949	.953
3.0	.939	.943	.942	.947	.946	.950	.949	.952	.951	.955	.954	.958
3.5	.944	.948	.946	.950	.950	.954	.952	.957	.956	.959	.958	.962

Table F 9 (Contd)

e_0^0 During Peroid:	65.0	67.5	67.5	70.0	70.0	72.5	72.5	75.0	75.0	77.5
r	E=62,5		E=65		E=67.5		E=70		E=72.5	
0.0	.913	.918	.915	.920	.917	.924	.921	.928	.923	.931
0.5	.923	.928	.925	.929	.927	.933	.930	.937	.933	.941
1.0	.931	.936	.934	.938	.936	.941	.939	.945	.942	.948
1.5	.938	.943	.938	.943	.944	.949	.947	.952	.950	.955
2.0	.946	.950	.948	.952	.951	.956	.954	.959	.957	.962
2.5	.951	.955	.954	.959	.956	.961	.960	.964	.962	.967
3.0	.957	.960	.960	.964	.962	.966	.965	.970	.968	.972
3.5	.961	.965	.964	.968	.966	.971	.969	.973	.972	.977

Table F. 10

VALUES OF $P^{t+5}_{25+} \,/\, P^{t}_{+-0}$ i.e., OVERALL SURVIVAL RATIOS FOR FIVE-YEAR PERIOD CORRESPONDING TO BASE RATE OF GROWTH, r, BASE EXPECTATION OF LIFE AT BIRTH, E AND EXPECTATION OF LIFE AT BIRTH DURING THE PERIOD FOR FEMALE POPULATION AGED 20+

e^o_0 During Period:	22.5	25.0	25.0	27.5	27.5	30.0	30.0	32.5	32.5	35.0
r	E=20		E=22.5		E=25		E=27.5		E=30	
0.0	.845	.856	.851	.861	.857	.866	.862	.871	.867	.876
0.5	.851	.862	.857	.867	.863	.873	.869	.877	.873	.882
1.0	.856	.867	.863	.873	.869	.878	.875	.883	.880	.888
1.5	.861	.872	.868	.878	.874	.883	.880	.889	.886	.894
2.0	.866	.876	.873	.882	.879	.888	.885	.893	.891	.898
2.5	.870	.880	.877	.886	.884	.892	.890	.898	.896	.903
3.0	.873	.883	.881	.890	.888	.896	.894	.902	.900	.907
3.5	.877	.886	.884	.893	.891	.899	.898	.905	.903	.911

Table F. 10 (Contd)

e_0^0 During Period:	35.0	37.5	37.5	40.0	40.0	42.5	42.5	45.0	45.0	47.5	47.5	50.0
r	E=32.5		E=35		E=37.5		E=40		E=42.5		E=45	
0.0	.871	.879	.875	.882	.878	.886	.882	.889	.886	.892	.889	.895
0.5	.878	.886	.882	.889	.887	.893	.890	.896	.893	.900	.897	.903
1.0	.885	.892	.889	.896	.893	.900	.897	.904	.900	.907	.904	.910
1.5	.891	.899	.895	.902	.900	.907	.903	.910	.907	.913	.911	.916
2.0	.896	.903	.901	.908	.905	.911	.909	.916	.915	.919	.917	.922
2.5	.901	.908	.905	.912	.911	.917	.914	.920	.918	.924	.923	.928
3.0	.904	.911	.910	.917	.915	.921	.919	.925	.923	.929	.928	.932
3.5	.910	.917	.914	.921	.919	.925	.923	.929	.928	.933	.931	.936

e_0^0 During Period:	50.0	52.5	52.5	55.0	55.0	57.5	57.5	60.0	60.0	62.5	62.5	65.0
r	E=47.5		E=50		E=52.5		E=55		E=57.5		E=60	
0.0	.891	.896	.895	.899	.896	.901	.899	.904	.901	.906	.903	.908
0.5	.899	.904	.902	.907	.904	.909	.907	.912	.910	.915	.912	.917
1.0	.907	.912	.909	.915	.912	.918	.915	.920	.918	.923	.921	.925
1.5	.914	.919	.916	.921	.919	.924	.923	.927	.926	.931	.928	.933
2.0	.920	.925	.923	.927	.926	.931	.929	.934	.932	.937	.935	.940
2.5	.926	.930	.929	.934	.932	.936	.935	.939	.939	.943	.941	.945
3.0	.930	.935	.934	.939	.938	.942	.941	.945	.944	.948	.947	.951
3.5	.936	.940	.938	.942	.942	.946	.945	.949	.948	.952	.951	.955

Table F. 10 (Contd)

e_0^0 During Period	65.0	67.5	67.5	70.0	70.0	72.5	72.5	75.0	75.0	77.5
r	E=62.5		E=65		E=67.5		E=70		E=72.5	
0.0	.905	.910	.908	.913	.910	.917	.914	.921	.917	.925
0.5	.915	.921	.917	.922	.920	.926	.923	.930	.927	.934
1.0	.923	.928	.926	.930	.928	.934	.932	.939	.935	.942
1.5	.930	.936	.930	.935	.936	.942	.940	.945	.943	.949
2.0	.938	.942	.940	.945	.943	.949	.947	.953	.950	.956
2.5	.943	.948	.947	.951	.949	.954	.953	.958	.956	.961
3.0	.949	.954	.953	.957	.955	.960	.958	.964	.961	.967
3.5	.954	.958	.957	.961	.960	.965	.963	.967	.966	.971

Estimation of Mortality from a Single Age Distribution of Population

M. L. Srivastava

The author has discussed a number of relationships between fertility and mortality characteristics in stable female population (1966 a, 1966 b, 1967). The approach has been through graphic analysis of characteristics in 42 stable female populations specially constructed for the purpose. The methodology of constructing these stable populations is discussed in the articles referred to and need not be repeated again. However, it may be mentioned that the level of fertility in these populations was determined by the value of the gross reproduction rate (GRR) and the age pattern of fertility was defined by the distribution of the GRR over the age groups 15–19, 20–24, ... , 40–44 years in the ratio 1:7:7:6:4:1 (United Nations 1956). The mortality levels and patterns were those given by U. N. (1956) Model Life Tables at specified levels. The main purpose of studying these relationships was to obtain simplified methods of estimating demographic characteristics in a population through Stable Population Theory. Thus, several graphs were presented for the purpose and it was assumed that at least two characteristics distinctly different (Coale, 1963) were available for estimation of others. It was stressed by Srivastava (1967) that the age distribution and the rate of population growth were easily obtainable and therefore knowing these two, others could be estimated through the application of the graphs.

It is quite possible, particularly in countries which have only one census record, that we have only the age distribution and not the rate of population growth. Or, even if we have these information, both might be subject to error. Thus, assuming that only the age distribution in the population is known, a method is developed here

which can facilitate estimation of various demographic characteristics in a population under study. In the present paper we will, however, confine our attention to the estimation of mortality level alone. The age distribution of the Indian population as in 1961 will be taken as an illustration.

Since our method uses only the age distribution in a population for the estimation of various demographic characteristics, it automatically eliminates the effect of error (if there is any) in observed rate of population growth on the estimates of demographic characteristics. This is a distinct advantage in using the method of estimation discussed in the present paper.

Method

The main principle of the methodology given here dwells on the graduation of the observed age distribution by the stable age distribution. For this, two moments of the former distribution (i.e., mean and variance) are equated to the respective moments of the latter. The difficulty of obtaining simple and explicit expressions which could be used for the estimation of demographic characteristics in the observed population, is solved to a great extent by exploiting the property of empirically observed interdependence of the two moments of stable age distributions satisfying certain conditions that relate to the patterns of fertility and mortality described earlier.

Table 1 presents the values of the mean and the percentage of coefficient of variation in stable female populations with specified values of GRR and the expectation of life at birth (e_0^0). These values are plotted on an ordinary graph paper with mean age (M_f) on the X–axis and the percentage of coefficient of variation (C_f) on the Y–axis. These points are shown in figure 1 wherein it may be noted points (M_f, C_f) referring to stable female populations defined by different values of GRR and the same schedule of mortality lie on an almost straight line. Thus we observe six straight lines each referring to a mortality schedule considered. Also, it may be noted that these straight lines form a set of almost parallel and stratified regions which permit an unique location of a point (M_f, C_f) for a stable female population with known GRR and e_0^0.

Table 1

MEAN (M_f) AND PERCENTAGE COEFFICIENT OF VARIATION (C_f) FOR AGE DISTRIBUTIONS OF STABLE FEMALE POPULATIONS WITH SPECIFIED VALUES OF THE GROSS REPRODUCTION RATE (GRR) AND THE EXPECTATION OF LIFE AT BIRTH (e_0^0)

GRR		e_0^0 for females					
		20.20	30.40	40.74	51.31	62.05	71.80
1.0	M_f	39.38	39.44	39.77	39.99	39.86	39.58
	C_f	52.21	54.11	55.42	56.61	57.98	59.20
1.5	M_f	33.57	33.18	33.12	33.00	32.61	32.16
	C_f	60.32	62.87	64.64	66.21	67.86	69.25
2.0	M_f	29.58	28.97	28.70	28.42	27.93	27.43
	C_f	66.19	69.04	71.08	72.80	74.47	75.94
2.5	M_f	26.70	25.96	25.57	25.21	24.69	24.19
	C_f	70.60	73.57	75.75	77.51	79.18	80.57
3.0	M_f	24.50	23.68	23.24	22.84	22.32	21.83
	C_f	74.04	77.11	79.26	81.00	82.62	83.92
3.5	M_f	22.75	21.91	21.44	21.02	20.51	20.05
	C_f	76.84	79.83	82.00	83.68	85.23	86.38
4.0	M_f	21.34	20.49	20.00	19.58	19.09	18.65
	C_f	79.10	82.09	84.15	85.75	87.17	88.26

Note : GRR is distributed over the age groups 15–19, 20–24, ... 40–44 years in the ratio 1 : 7 : 7 : 6 : 4 : 1.

Mortality pattern is given by U.N. model life tables with specified e_0^0.

To complete the estimation for the total population, we needed a graph similar to figure 1 for stable male populations. This necessitated the calculation of stable age distributions for males. The following method was used to arrive at these age distributions. The intrinsic rates of growth for stable female populations obtained by combining specified values of GRR and e_0^0 for females were assumed to represent such rates for male populations. These assumed rates were combined with the mortality schedules for males given by U.N. Model life tables at levels corresponding to those used for female populations and the stable age distribution and other

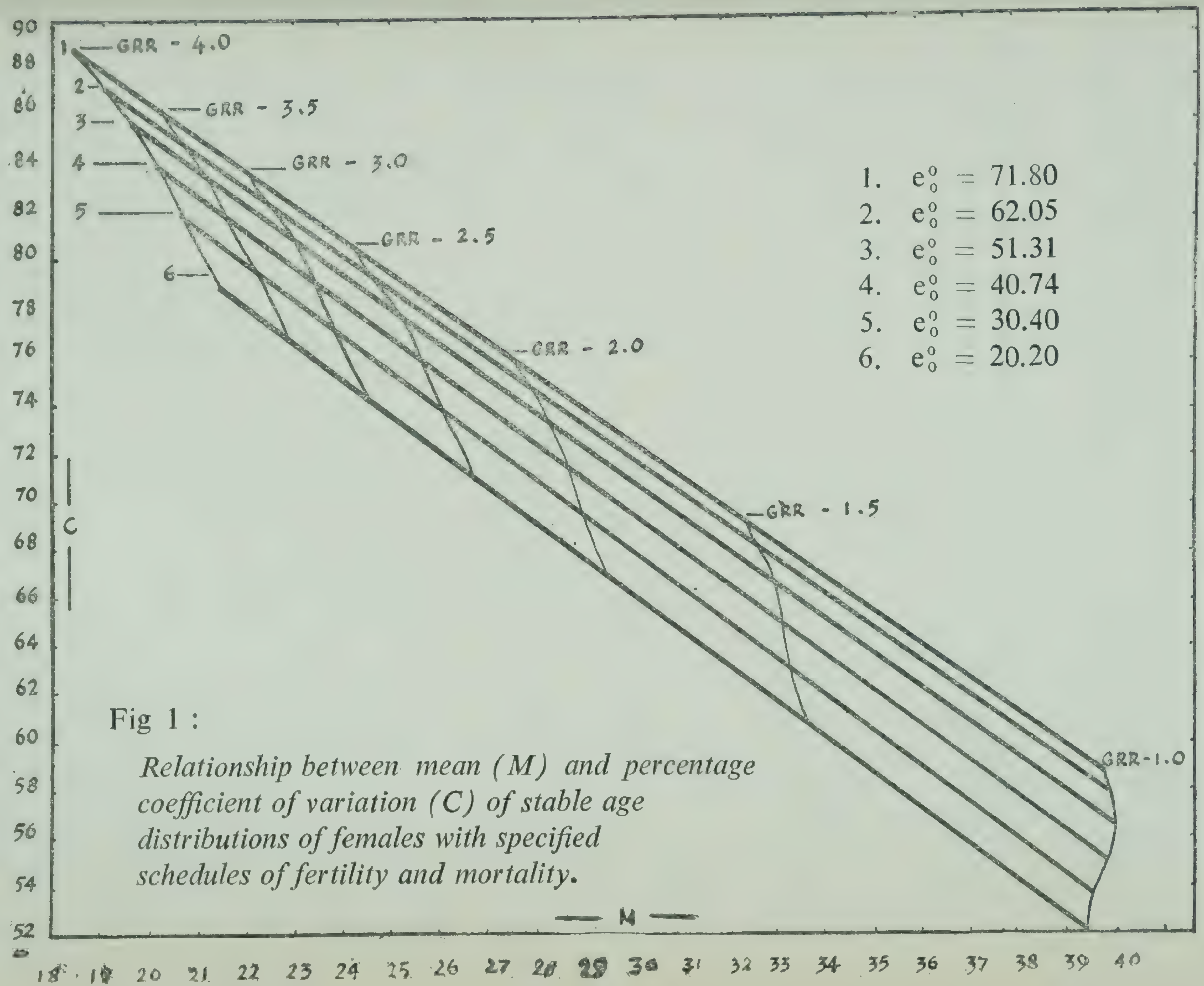

Fig 1 :

Relationship between mean (M) and percentage coefficient of variation (C) of stable age distributions of females with specified schedules of fertility and mortality.

characteristics for males were obtained. The formulae used can be obtained in several sources (Abdel Aty, 1961; Glass, 1940; Srivastava 1965, 1966 a). It may be noted that the same level of U. N. model life tables gives different schedules of mortality for males and females. Thus our stable male and female populations have the same rate of growth but different mortality schedules corresponding to the same general level of mortality of U.N. model life tables.

Table 2 gives the values of the mean (M_m) and the percentage coefficient of variation (C_m) for the age distributions of

Table 2

MEAN (M_m) AND PERCENTAGE COEFFICIENT OF VARIATION (C_m) FOR AGE DISTRIBUTIONS OF STABLE MALE POPULATIONS WITH SPECIFIED VALUES OF THE GROSS REPRODUCTION RATE (GRR) AND THE EXPECTATION OF LIFE AT BIRTH (e_0^o)

GRR		e_0^o for males					
		19.80	29.57	39.24	48.72	58.82	68.56
1.0	M_m	38.00	38.28	38.66	38.75	38.57	38.33
	C_m	52.08	54.21	55.74	57.11	58.52	59.69
1.5	M_m	32.64	32.38	32.33	32.09	31.67	31.27
	C_m	59.59	62.54	64.55	66.34	68.05	69.43
2.0	M_m	28.95	28.42	28.13	27.74	27.23	26.78
	C_m	65.11	68.40	70.74	72.64	74.44	75.80
2.5	M_m	26.28	25.55	25.15	24.68	24.15	23.69
	C_m	69.25	72.88	75.19	77.23	78.96	80.29
3.0	M_m	24.21	23.41	22.92	22.42	21.89	21.45
	C_m	72.57	76.12	78.62	80.60	82.28	83.50
3.5	M_m	22.57	21.72	21.19	20.69	20.16	19.74
	C_m	75.28	78.55	81.31	83.18	84.82	85.92
4.0	M_m	21.22	20.35	19.81	19.31	18.80	18.39
	C_m	77.57	81.03	83.39	85.19	86.76	87.87

Note : a. Fertility and mortality schedules are the same as noted in footnote to Table 1.

b. GRRs refer to female births and female populations as in Table 1.

stabe male populations described in the preceding paragraph. The sets of points (M_m, C_m) in 42 stable male populations with specified combinations of GRR (in relation to female births) and e_0^0 for males as shown in figure 2 exhibit a feature similar to that of figure 1.

Figures 1 and 2 bring out the relationship that for a given level of e_0^0 (for either male or female) the percentages coefficient of variation and the means of stable age distributions of either sex are linearly related. Also, a change in the value of e_0^0 within the set of e_0^0's considered shows that the linear relationships are almost parallel. This property is exploited in the following paragraphs to estimate the level of mortality in India. In fact other demographic characteristics can also be estimated but these will be discussed in a subsequent paper.

Application of Figures 1 and 2

Figures 1 and 2 can be used to estimate the level of e_0^0 respectively for females and males in a population. This will imply that the populations have stable age distributions and experience the patterns of fertility and mortality that are associated with these figures. The method of estimation described below is based on the graphic interpolation and considers the female populations as an illustration.

For the observed age distribution of females calculate the mean age (M'_f) and the percentage coefficient of variation (C'_f). The estimates (M'_f, C'_f) can be used to locate a point in figure 1. The values of e_0^0 for females corresponding to two straight lines which fall on either side of this point can then be determined. Simple interpolation of these values of e_0^0 for females in proportion to the perpendicular distance between the straight lines which are on either side of the point (M'_f, C'_f) will yield the value of the level of e_0^0 for females in the population. To facilitate interpolation, the four points of figure 1 which enclose the point (M'_f, C'_f) can be enlarged on a simple graph paper. Once the level of e_0^0 is obtained, the values of the probability of dying within five years of age (${}_5q_x$) can be obtained by interpolating (${}_5q_x$) values of U.N. model life tables that refer to e_0^0's which lie on either side of the estimated e_0^0 in the

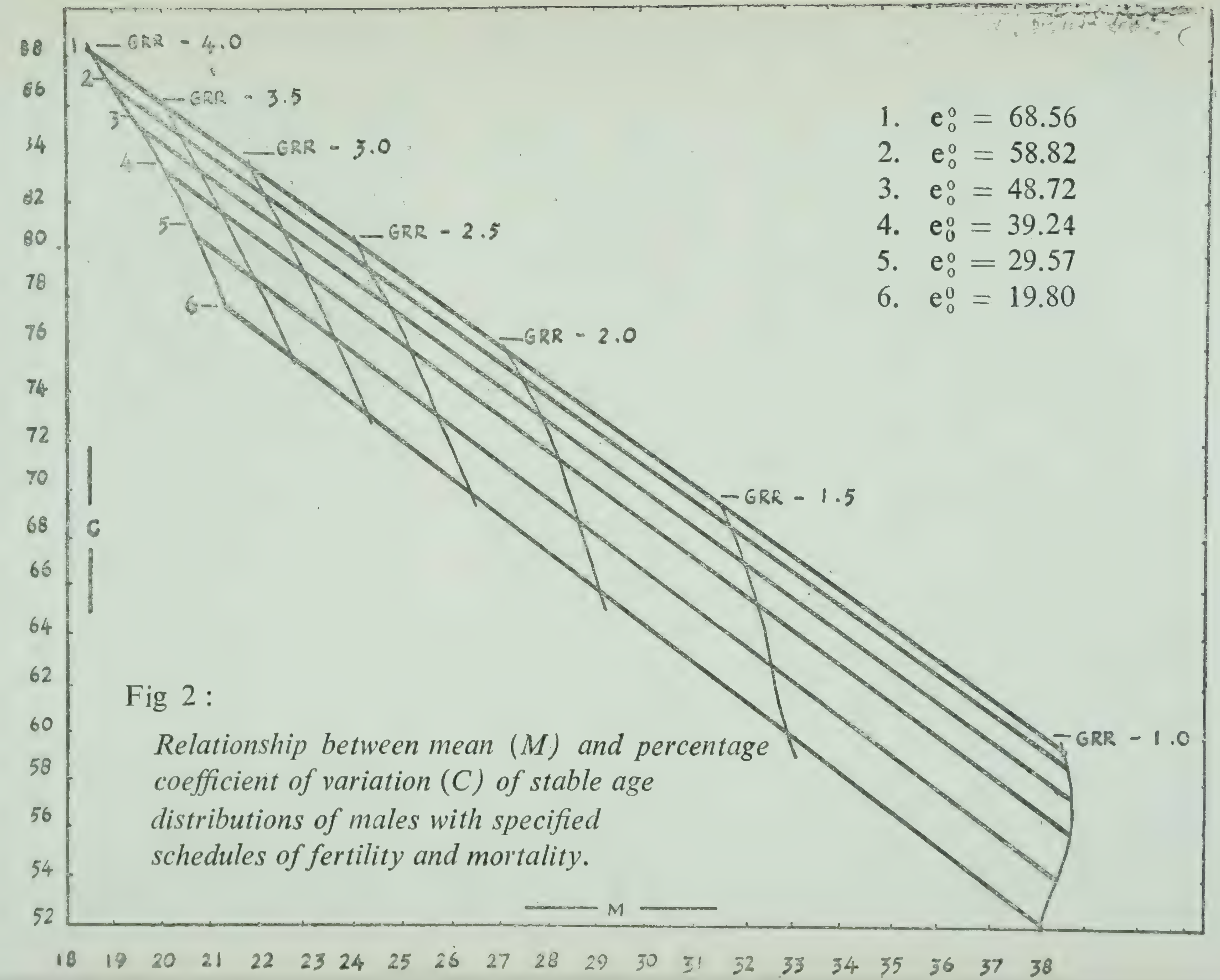

Fig 2 :

Relationship between mean (M) and percentage coefficient of variation (C) of stable age distributions of males with specified schedules of fertility and mortality.

population. The interpolation factor will remain the same as that for estimating e_0^0 from figure 1. Other columns of the life table can then be obtained easily.

A similar procedure may be adopted for obtaining the level and pattern of mortality for male population from figure 2. It may be pointed out here that figures 1 and 2 can also be used to estimate the level of the gross reproduction rate in the population. Using the estimate of GRR and e_0^0, estimates of other demographic characteristics in the population can be obtained.

Table 3

PERCENTAGE DISTRIBUTION OF PERSONS ACCORDING TO AGE AND SEX, INDIA, 1961

Age group (in year)	Males		Females	
	Unadjusted (observed)	Estimated	Unadjusted (observed)	Estimated
(1)	(2)	(3)	(4)	(5)
0–4	14.69	15.33	15.48	15.86
5–9	14.63	12.87	14.86	13.18
10–14	11.62	11.41	10.83	11.57
15–19	8.23	10.21	8.13	10.15
20–24	8.05	8.88	9.00	8.82
25–29	8.20	7.74	8.49	7.61
30–34	7.07	6.73	6.98	6.54
35–39	6.02	5.82	5.58	5.60
40–44	5.35	5.00	5.06	4.78
45–49	4.31	4.23	3.91	4.04
50–54	4.04	3.50	3.75	3.37
55–59	2.34	2.81	2.14	2.75
60–64	2.52	2.16	2.60	2.15
65–69	1.09	1.55	1.12	1.58
70–74	0.95	1.00	1.06	1.05
75–79	0.38	0.54	0.40	0.59
80–84	0.32	0.23	0.39	0.26
85 +	0.19	0.08	0.22	0.10
Total	100.00	100.00	100.00	100.00
Mean	24.49		24.18	
Standard deviation	18.83		18.92	
Percentage coefficient of variation	76.89		78.24	
D (cf. text)	0.0450		0.0455	

Source: Computed from Col. (2) and (4), Census of India, Age Tables 1963.

Numerical Application

Table 3 (page 141) presents the observed age distribution of males and females in India as on 1961. The mean, standard deviation and the percentages coefficient of variation of these are distributions are also given in the table. Corresponding to the pair of value of mean age and the percentage coefficient of variation of the age distributions of female or male, a point was located either on figure 1 or 2. A set of values referring to four pairs of GRR and e_0^0 which enclosed the point on these figures was obtained and an enlarged figure was drawn on a separate graph paper. This interpolation is performed in a manner indicated earlier and the results are summarised below. Our estimates of e_0^0 for females and males are compared with some other estimates for the year 1961.

Various estimates of e_0^0 according to sex, India, 1961.

Sex	Type of estimate		
	Ours	Census Actuary*	Das Gupta**
Female	44.26	37.40	45.2
Male	43.80	38.73	49.0

* Obtained by combining the observed inter-censual annual rate of population growth and the observed age distribution with reference to U. N. model life table, Census of India (1963).

** P. Das Gupta (1971), obtained by combining the estimated annual rate of population growth in 1961 and the observed age distribution and the U. N. model life tables.

It may be noted in the above table that e_0^0 for females in India in 1961 turn to be higher than that for males. This phenomenon is not observed in either Das Gupta's or census actuary's estimates. The trend is worth nothing even though our estimates of e_0^0 are not directly comparable to those obtained by Das Gupta or by Census actuary because of the difference between the input data (cf. footnote to above table). Our method yields the value of the rate of population growth as a by-product of the estimation process and thus it can provide an opportunity of testing the accuracy of census count.

Once the levels of e_0^0 have been obtained, lx and Lx columns corresponding to the estimated level of e_0^0 can be obtained by

interpolating the respective columns of U.N. model life tables as indicated earlier. The construction of life table, then, becomes an easy exercise. Also, other demographic characteristics in the population can be estimated by interpolating the ratee provided by Srivastava (1967). For example, for the 1961 age distribution given in Table 3, the annual intrinsic birth, growth and death rates per 1000 males were 39.84, 19.46 and 20.38 respectively. The corresponding rates for females were 40.91, 20.73 and 20.18. The GRR for female births per female was estimated as 2.78. The estimated stable age distributions that corresponded to the observed ones for males and females are also given in Table 3. The observed and the estimated age distributions are compared with the help of D— the sum of positive differences between observed and estimated proportions of total populations in each five-year age group. The values of D for males and females obtained as 0.0450 and 0.0455 respectively suggest that the fit was equally good for the two sexes separately.

Three significant points brought out by this analysis may be noted.

1. If the age distribution as smoothed by the Census actuary is used instead of the unsmoothed age distribution the e^0_0 is likely to be less, somewhere near 40. The smoothing procedure introduces some artificiality in the age distribution and besides the smoothed age distribution heavily depends upon the method of smoothing adopted. It is difficult to say whether such smoothed age distribution should be used in the absence of the knowledge about the real situation.

2. The estimated level of e^0_0 for females is higher than that for males. This is contrary to several other findings of e^0_0 for 1961.

3. The intrinsic rate of annual growth for females is higher than that for males. This is contrary to the observed pattern where the inter-censual and annual rates of growth per 1000 females and males were obtained as 19.26 and 19.80. The possibility of undercount of females in Indian Census cannot be ruled out completely.

As the primary aim of the paper is to provide a methodology to estimate e_0^0 by using only the census age distribution, the data and calculations presented here may be taken only as illustrations. However, further investigation is being carried out to locate the differences that have been brought out by the present analysis and the results will be presented in a subsequent paper.

NOTES

1 Abdel-Aty, S.H. (1961) "Life-Table fuctions for Egypt based on model life-tables and quasi-stable population theory", *The Milbank Memorial Fund Quarterly*. vol. 39, pp.351-352.

2 Census of India (1963) *Age Tables 1961 Census, Paper No. 2 of 1963,* pp. 50—60.

3 Coale A.J. (1963) "Estimates of various demographic measures through the Quasi-stable age distributions" in *Emerging Techniques in Population Research,* Milbank Memorial Fund, p. 177.

4 Das Gupta, P. (1971) "Estimation of demographic measures for India 1881-1961, based on census age distributions," *Population Studies*, vol. 25 (3) p. 410.

5 Glass D.V. (1940) *Population Policies and Movements in Europe* (Appendix 5) Oxford at the Clarendon Press.

6 Srivastava M.L. (1965) "The Quantitative Effect of Some Socio-Demographic Factors on Measures of Fertility" (Ph. D. Thesis) the Australian National University.

7 Srivastava, M. L. (1966 a) "The relationship between the birth rate and the death rate in stable populations with the same fertility but different mortality schedules". *Eugenics Quarterly,* Vol. 13. pp.231—239.

8 Srivastava, M. L.(1966 b) "Some comments on the approximate relationships between the birth rate and the death rate in stable populations," *Patna University Journal,*vol. 21 (4) pp. 1-13.

9 Srivastava, M. L. (1967) "The relationships between fertility and mortality characteristics in stable female populations," *Eugenics Quarterly* vol. 14, pp. 171—180.

10 United Nations (1956) *Methods for Population Projections by Sex and Age* ST/SOA/Series A, Population Studies No. 25.

Some Indices of Differential Mortality in India

K. E. Vaidyanathan

Introduction

The study of differential mortality, namely the differences in mortality between various subgroups of a population has been of great concern to demographers and medical researchers seeking to improve the health and longevity of the population. Despite this concern, our understanding of the influence of socio-economic factors on mortality as against other characteristics like sex and age are rather limited especially for the developing countries. There are two factors that may have contributed to this gap in our knowledge, namely, a) the lack of adequate and reliable data, and b) the inadequacy of conventional indices of differential mortality under the circumstances of lack of data prevalent in the developing countries. Studies in different parts of the world have shown as a general rule that these populations or classes of populations which are in a relatively favourable position from economic and social points of view tend to have lower mortality rates than more retarded groups[1].

In India the relative lack of investigations pertaining to the relationship between socio-economic status and mortality largely arises from the difficulty in obtaining the necessary data. The death certificate in India does carry information on the religion and caste and occupation of the deceased person. These characteristics are not in themselves adequate for determining the socio-economic status of the deceased person. It would help if information is elicited on the educational attainment and income and the type of house where the deceased person had been living, but this will call for a separate enquiry to obtain this information.

Even granting that these particulars have been included in the death certificate, there is the additional problem arising on account

of the differential underregistration of persons belonging to various socio-economic groups. Although there have been no studies to show the nature of this differential one might suspect a direct relationship between socio-economic class and extent of completeness of registration. A second problem arises from the fact that the base population required for working out the specific death rates for each socio-economic group has to come from the census. In the first place, census is not taken on an annual basis unlike the death registration and secondly the two sources do not follow the same procedure in recording occupation. The task of matching the two records is well nigh impossible in a country like India where the same person has several aliases and his conception of age is as good as the enumerator's ingenuity.

Some Indices of Differential Mortality

The limitations of the crude death rate are well known. It is affected by the age-sex structure of the population for which it is computed. This limitation is overcome by computing the Comparative or Standardized Mortality Ratios[2]. These two ratios should be nearly equal except when the excess mortality in a population subgroup is concentrated in the age groups where the numbers in the subgroup predominate. Also the SMR is more affected by random fluctuation than the CMR. Another measure which is commonly used is the infant death rate defined as the ratio of the number of infant deaths in a given year to the number of live births to persons belonging to a given sub-group of population during the same period. The computation of these measures requires data on death rates and infant death rates by social classes of reasonable accuracy which is difficult to find in developing countries. The primary cause of the inadequacy of death data is believed to be registration errors, in particular, failure to report deaths and especially omission of very young infants whose birth and death is not remembered or placed correctly in time.

It is therefore necessary to work out certain less sensitive, but more feasible measures of differential mortality for a country like India. The following measures are suggested in this paper.

Proportion of widows to total or evermarried females preferably by age groups and if this is not available at least for a terminal age group like 45 and over:

The rationale of this index is obvious for a country like India where social customs and traditions keep widow remarriage to a minimum[3]. Under these circumstances, the proportion widowed will be related to the joint probability of the woman as well as her husband surviving up to a given age, or mortality conditions of the husband and wife. If we can assume that, the difference between the ages of husband and wife do not differ between several population groups and the propensity to remarry is the same among them, the difference between different groups in the proportion widowed might reflect differential mortality. As pointed out earlier, this is indeed a very crude measure, and will be distorted to the extent these assumptions are violated. One more factor, the duration of exposure to mortality (namely, the age of woman) will affect this index. This can be controlled by working out this index for specific age for comparison between different population groups.

Proportion of children who do not survive to the children ever born by age of mother, and if this is not available at least for those women of completed fertility 45 and over:

This proportion will be influenced by two factors—one is the probability of dying and the other is the duration of exposure to mortality. The level of fertility also may have an influence on this proportion but we may assume that the differences in the fertility levels between different population groups may not be large enough to affect this index. As in the case of the earlier index, the duration of exposure to mortality can be controlled by working out this index specific to the age of mother. The proportions thus obtained for the different population groups may be expressed as relative to the proportion for all categories to indicate differentials in mortality.

Mean loss of children per married woman by age or at least for women of completed fertility :

It may be noticed that this measure is obtained in the same way as the previous measure except that the denominator is the number

of women experiencing the loss of children instead of the number of children ever born. This index amounts to multiplying the previous index by the average number of children born per woman. This measure will provide an indication of differential mortality if there is no significant difference in the average number of children born among the different sub-groups of population. While there are differences between population sub-groups as regards the average number of children ever born, surveys in different parts of the country show that these differences are not large[4].

Proportion of deaths at ages 50 and over to deaths at ages 5 and over:

The advantage of this measure lies in the fact that both numerator and denominator comes from the same source, namely registration or sample survey. This index is similar to the Proportional Mortality Ratio[5], except that in the denominator deaths in the age group 5 and above is preferred to total deaths which include infant deaths and children upto 5 years old which are known to be deficient. This proportion is directly related to the expectancy of life at birth[6]. This proportion computed for different population groups may be expressed as relative to the overall proportion to reflect differential mortality. Misstatement or ignorances of age would have little effect on the accuracy of this indicator in as much as it depends on a dichotomous age classification only (5—49 and 50+). Also if deaths are underreported uniformly throughout the age span, the underreporting would have little effect on the reliability of this indicator.

Proportion of all deaths due to infectious and parasitic diseases:

It is well known that as the expectancy of life improves, the spectrum of mortality by causes undergoes a change from one in which there is a predominance of infectious and parasitic diseases to that of deficiency diseases. Therefore, one may expect the proportion of deaths due to infectious and parasitic diseases to reflect the current mortality situation approximately. The assumption is that the extent of underreporting of deaths due to infectious and parasitic diseases will be approximately of the same order to that of the deaths from all causes. This assumption may or may not hold good, as experience in India shows that many deaths are reported as due to

fevers, or some such unspecified causes. The accuracy in the reporting of causes of deaths may itself be related to the socio-economic status, education and occupation of the deceased and consequently the difference in this index between these population groups may not reflect the true nature of the differentials in mortality. Therefore, this index should be interpreted with caution in situations where the data are known to be in error.

Some Evidences Concerning Differential Mortality in India

We shall now examine some of the information available from recent surveys in different parts of India to give some indication of the picture of differential mortality in India. We shall consider geographic and rural-urban differentials and differentials according to religion and caste, occupation, education, socio-economic status etc. These have been chosen for consideration firstly, because experience from studies in developed countries seem to suggest the importance of these in contributing to differentials in mortality. Secondly, these are the factors for which the relevant information could be obtained.

Geographical Variations :

Within every country there are significant differentials in mortality between regions arising from differences in urbanism occupational structure and other social and economic factors. The data on geographical variations in mortality based on the National Sample Survey seventh and fourteenth rounds shown in Table 1 indicate that the central zone comprising of Uttar Pradesh and Madhya Pradesh have consistently higher death rate compared to the All-India death rate and the East and South zones have generally lower death rates. It should be pointed out that these rates based on the National Sample Survey are subject to sampling errors and differential efficiency of the survey in the different parts of the country. Also crude death rate is affected by differences in age-sex composition. The lack of accurate data to provide an indication of the mortality in different states and districts is one of the major gaps in Indian demographic knowledge.

Rural-Urban Differentials:

Past studies in different parts of the world do not show any consistency in urban-rural differentials in mortality. Mortality rates in Europe and the United States during the nineteenth century and early part of this century were reported to be higher in urban areas than in rural areas. At present the rural-urban differentials in

Table 1

GEOGRAPHICAL VARIATIONS IN MORTALITY IN INDIA BASED ON DIFFERENT ROUNDS OF NATIONAL SAMPLE SURVEY

Zone	7th round rural death rate 1953–54	Index (percentage of India)	14th round rural death rate 1958–59	Index (percentage of India)	IMR A 14th round 1958	Index (percentage of India)	IMR B 14th round 1958	Index (percentage of India)
North	18.5	105.1	15.8	83.2	111	89.8	143	89.9
East	17.6	100.0	16.0	84.2	107	85.6	118	74.2
South	11.7	66.5	14.0	73.7	105	84.0	142	89.3
West	12.3	69.9	17.9	94.2	116	92.8	158	99.4
Central	23.9	135.8	27.8	146.3	153	122.4	197	123.9
All India	17.6	100.0	19.0	100.0	125	100.0	159	100.0

IMR A : Infant mortality rate based on an average exposure of 6 months

IMR B : Conventional infant mortality rate

North : Rajasthan, Punjab, Delhi, Himachal Pradesh, Jammu-Kashmir

East : Bihar, Orissa, West Bengal, Assam, Manipur, Tripura

South : Andhra Pradesh, Madras, Kerala

West : Maharashtra, Gujarat, Mysore

Central : Uttar Pradesh, Madhya Pradesh

Source : National Sample Survey Seventh and Fourteenth rounds

mortality appear to be small in the developed countries and in some cases no longer in favour of rural areas[7]. Evidence of rural-urban mortality differentials in India are provided by the Mysore Population Study and the National Sample Survey (see Table 2).

The estimated crude death rate for Bangalore city, about 14 per 1000 persons, is lower than the rates obtained for rural Zones II

and III, but about the same as that for Zone I. The lower death rate may be partly due to the greater underregistration of death in Bangalore City and also a more favourable age composition of the population due to migration. However, these differences are consistently found in two other measures namely, the percentage of widows among females and percentage of loss of children to children ever born. It may be noted that the proportions of widowed women is much higher in the rural than in the urban area reflecting a higher mortality in rural area than in urban area although the migration of widows may also be a factor. The proportion of loss of children follows a similar pattern, that for women 45 and over being one-third higher in rural area without anti-malarial operations than for Bangalore City. Recent rounds of the National Sample Survey also corroborate their findings[8]. This may be due to the fact that bulk of the hospital facilities and doctors are concentrated in our urban areas, and the urban areas also tend to have better drainage and protected water supply.

Table 2

SOME EVIDENCES OF DIFFERENTIAL MORTALITY BETWEEN CITY, TOWNS AND RURAL AREAS, MYSORE POPULATION STUDY, 1950-1951

		Zone I (Rural hills with malarial operation	Zone II (Rural hills without anti-malarial operation)	Zone III (Rural Plains)	Towns	Bangalore City
A:	Crude death rate	15.1	18.9	18.6	13.8—23.9	13.7
B:	Percentage of widowed women to all women by age groups					
	15—44	14.7	14.3	11.6	11.0	8.2
	45+	72.4	75.4	65.3	67.1	62.0
C:	Percentage loss of children ever born					
	15—24	23.7	26.0	25.0	25.3	20.4
	25—34	28.9	32.2	28.9	26.3	23.9
	35—44	34.7	31.7	31.4	29.8	26.1
	45+	43.9	46.3	38.0	39.2	34.2

Source: United Nations *Mysore Population Study*, *op cit* pp. 82, 114 and 115.

Religion and Caste :

Studies in different parts of India (see Table 3) seem to indicate mortality differentials between different caste and religious groups in the country. In general, Christians and Muslims seem to have lower mortality than Hindus and among the Hindus the upper caste groups have generally lower mortality than the lower castes. In the West, ethnic and racial differentials in mortality have been narrowing down in recent years presumably due to the more similar environmental conditions these groups experience. It is not clear whether such a narrowing down of mortality differentials among religious and caste groups is taking place in India.

Occupation :

Evidences of occupational differentials in mortality are available from the Shadnagar Standard Fertility Survey[9]. These are presented in Table 4. These figures indicate that owner and tenant cultivators and white collar workers have generally lower mortality and agricultural labourers and blue collar workers have higher mortality than the mortality for all classes. This finding is in general agreement with findings of such studies elsewhere which show an inverse relationship between occupational class and mortality[10]. This may partly be accounted by the greater risks in occupations held by the lower classes and partly by the level of living associated with each.

Educational level :

The study carried out by D. N. Saxena provides some interesting evidences of education differentials in mortality (See Table 5) based on child survival indices worked out according to education of father and mother[11]. The data seem to indicate an inverse relationship between mortality of children and educational attainment of parents.

Socio-Economic status:

A scheme for socio-economic status classification suitable to the Indian situation is yet to be worked out. In the absence of a standard procedure, scholars have resorted to different approaches

Table 3

SOME INDICES OF DIFFERENTIAL MORTALITY BY RELIGION AND CASTE

A. Based on Shadnagar Survey, 1966-68[1]

Religion and caste (a)	Infant Mortality Rate	Index (per cent of all categories)	percentage of deceased children to children ever born			
			To women aged 45–49	Index (per cent of all categories)	To women aged 15–44	Index (per cent of all categories)
Hindus	112.3	104.9	32.4	100.9	27.1	103.0
Upper castes	119.0	111.1	28.2	87.9	18.0	68.4
Middle castes	111.1	103.7	32.7	101.9	27.0	102.7
Lower castes	117.6	109.8	34.1	106.2	32.7	124.3
Muslims	69.8	65.2	30.2	94.1	19.1	72.6
All Categories	107.1	100.0	32.1	100.0	26.3	100.0

B. Based on Lucknow Survey, 1967-68[2]

Religion and caste (b)	Infant Mortality Rate	Index (per cent of all categories)	Percentage of deceased children to children ever born to mothers of age 45 +	Index (per cent of all categories)	Mean number of deceased children per mother of age 45 +	Index (per cent of all categories)
Hindus	70.0	94.6	35.6	96.7	2.2	100.0
Upper castes	59.0	79.7	26.6	72.3	1.5	68.2
Middle castes	69.0	93.2	51.8	140.8	3.1	140.9
Lower castes	136.0	183.8	62.3	169.3	4.8	218.2
Muslims	94.0	127.0	40.1	109.0	2.4	109.1
All categories	74.0	100.0	36.8	100.0	2.2	100.0

Source : [1] Computed from *Shadnagar Standard Fertility Survey : Interim Report op cit* Table 4.6, 6.2 (a)

[2] Computed from D. N. Saxena, *Social Context of Fertility and Family Planning,* chapter III.

(a) Upper caste includes Brahmins; Vysyas, and Reddys; Middle caste includes all artisan castes and some backward castes; Lower castes include scheduled castes and tribes.

(b) Upper castes include Brahmins, Thakur, Vaishya and Kayastha; Middle castes include all 29 artisan castes such as Teli Nai, Kahar etc., and Lower castes include all ex-untouchable castes and scheduled castes.

Table 4

SOME INDICES OF DIFFERENTIAL MORTALITY BY OCCUPATION BASED ON THE SHADNAGAR SURVEY, 1966—68

Occupational category	Infant Mortality Rate	Index (Per cent of rate for all categories)	Percentage loss of children to children ever born to women 15—14	Index (Per cent of all categories)	Percentage loss of children to children ever born to women 45+	Index (per cent of all categories)
1. Owner tenant cultivators	104.4	97.5	22.1	84.0	30.6	95.6
2. Agricultural & casual labourers	101.1	94.4	29.8	113.3	34.7	108.4
3. White collar workers*	100.0	93.4	22.5	85.6	37.2	116.3
4. Blue collar workers†	149.8	139.9	27.7	105.3	27.9	87.2
All Categories	107.1	100.0	26.3	100.0	32.0	100.0

* Professionals, local government officials and businessmen

† Caste occupations, toddy makers and others

Source : Computed from *Shadnagar Standard Fertility Survey: Interim Report* op cit Tables 4.7 and 6.3 (a)

Table 5

SOME INDICES OF DIFFERENTIAL MORTALITY OF CHILDREN BY EDUCATIONAL LEVELS OF PARENTS, LUCKNOW SURVEY, 1967—68

Level of Educational attainment	Infant Mortality Rate	Index (per cent of all categories)	Percentage of deceased children ever born to mothers of age 45 +	Index (per cent of all categories)	Mean number of deceased children per mother of age 45 +	Index (per cent of all categories)
A. *Educational Level of Father*						
Illiterate and literate without schooling	121	155.1	48.7	142.4	3.2	160.0
Below Primary and Primary	62	79.5	35.3	103.2	1.9	95.0
Secondary and Higher	63	80.8	27.3	79.8	1.6	80.0
All Categories	78	100.0	34.2	100.0	2.0	100.0
B. *Educational Level of mother*						
Illiterate and literate without schooling	103	132.1	43.8	132.3	2.6	136.8
Below Primary and Primary	38	48.7	29.8	90.0	1.7	89.5
Secondary and Higher	79	101.3	12.1	36.6	5.0	263.2
All Categories	78	100.0	33.1	100.0	1.9	100.0

Source: Computed from D. N. Saxena *op cit* chapter III.

for measuring socio-economic status. The Mysore Population Study has made use of Type of Housing and Type of Lighting as a proxy for socio-economic status in urban areas (See Table 6) and economic status of household in rural areas (See Table 7). The implicit

Table 6

CRUDE DEATH RATES AND INFANT MORTALITY RATES BY TYPE OF HOUSE AND TYPE OF HOME LIGHTING AS PERCENTAGES OF RATES AND FOR BANGALORE CITY AND TOWNS

Type of house and type of lighting	Bangalore city			Towns		
	No. in Sample	CDR as % of Rate for all classes	IMR as % of Rate for all classes	No. in Sample	CDR as % of Rate for all classes	IMR as % of Rate for all classes
All classes	24515	100	100	6202	100	100
Type of house						
Hut or mud house with the tiled roof	1.679	161	111	1077	121	175
Mud house with tiled roof or brick, stone or cement house	22836	96	99	5125	95	84
Type of lighting						
Crude lamp	6387	108	108	2499	117	120
Lamp or lantern with chimney	8054	109	121	1662	68	126
Ele. light	10074	88	77	2041	80	58

Source : United Nations, *The Mysore Population Study*, Population Study No. 34. UN Dept of Economic and Social Affairs, New York, 1961. page 81.

Table 7

CRUDE DEATH RATES AND INFANT MORTALITY RATES BY ECONOMIC STATUS OF THE HOUSEHOLD AS PERCENTAGES OF RATES FOR THE RURAL ZONES

Economic Status of the household	No. of persons sample	DR as % of Rate for all classes	IMR as % of Rate for all classes
All classes	23314	100	100
Working on land			
Labour or temporary tenant	3688	98	159
Owner cultivator or permanent tenant with less land	3609	114	123
Owner cultivator or permanent tenant with more land	9179	92	95
Not working on Land			
Employee or unpaid family worker	2210	90	101
Employer or Own account worker	2290	105	99

Source: UN *Mysore Population Study* p. 81

assumption in this scheme is that in urban areas mud houses and crude lamp lighting are associated with lower strata of society and tiled houses and electrical lighting are found in the middle and upper strata of society. In Bangalore City the infant mortality rate for population living in huts or mud houses with thatched roof, and for those without electric lighting was about 11 per cent higher than the rate for the whole city population, whereas among the population in homes with electric lighting the infant mortality rate was only three-fourth of the overall rate. In the rural areas the families of agricultural labourers and temporary tenants had the highest infant mortality rate, 59 per cent above the rural rate per 1000 births; and the "owner cultivator" group having more than 3 acres of land had the lowest rate which was 5 per cent below the infant mortality rate for the rural areas as a whole. The infant mortality rate was less in the non-agricultural than in the agricultural population in rural areas.

Some studies (See Table 8) have used income as the basis for socio-economic status. Despite the differences in the classification adopted these studies seem to indicate an inverse relationship between income and mortality. It is likely that the poorer sections of the society do not receive adequate medical attention in contrast to the well-to-do sections and consequently the mortality is higher in the former class. Even where an inverse relationship exists between social class and mortality in a population, the relationship may differ for different causes of death. This is an area where studies are needed in India.

Table 8

SOME INDICES OF DIFFERENTIAL MORTALITY OF CHILDREN BY INCOME OF PATTERN, LUCKNOW SURVEY, 1967—68

Level of monthly income (in Rs)	Infant death Rate		Deaths per 1000 Live births to women aged 45 +		Average No. of children dead to women aged 45 +	
	No.	Index per cent at all categories	No.	Index per cent at all categories	No.	Index per cent at all catego-ries
Less than Rs.	136	203.0	370	1570	3.8	172.7
Rs. 75—150	87	129.9	511	140.8	3.1	140.9
Rs. 150—300	80	119.4	269	74.1	1.6	72.7
Rs. 300+	18	26.9	261	71.9	1.4	63.6
All categories	67	100.0	363	100.0	2.2	100.0

Source : Computed from D. N. Saxena *op cit* chapter III.

Concluding Remarks

This paper discusses the problems in the study of differential mortality in a developing country like India and suggests some alternative measures that could be followed and are being followed. Some of the illustrative data presented from surveys in different parts of the country seem to indicate a higher mortality among the Hindus than among the Christians and Muslims, an inverse relationship between mortality and socio-economic status, income, education and occupation. These studies are not adequate to throw light on whether such differentials are narrowing down or whether they vary from one area to another, or whether particular diseases or causes of death have any influence on these differentials. These call for carefully designed field studies in different parts of the country based on standard procedures of measurement and classification.

NOTES

1 United Nations, *Determinants and Consequences of Population Trends* (ST/SOA/ser. A, Population Studies No. 17) pp. 61—64.

2 The age distribution of the entire population is taken as the standard population and the actual age specific death rates for the given population sub-group (example social class, occupation etc..) is applied to it to arrive at the "expected" death rate. The ratio of the "actual" to the "expected" death rate is the Comparative Mortality Ratio. Alternatively the age specific death rates for the entire population is applied to the sub-group population to arrive at an "expected" death rate. The ratio of the "actual" to the expected death rate is the Standardized Mortality Ratio. These two methods correspond to the direct and indirect methods of standardization respectively. See B. Benjamin *Health and Vital Statistics,* George Allen and Unwin Ltd. London 1968 p. 126.

3 The proportion of ever remarried to ever married women is only 7 per cent in Kumudini Dandekar's *Demographic Survey of Six Rural Communities* (Gokhale Institute of Politics and Economics, Poona, 1959) and ranged between 2.8 per cent in Zone I to 4.5 per cent in Zone II in the United Nations *Mysore Population Study* (United Nations Dept. of Economic and Social Affairs, New York 1961, ST/SOA/series A/34, page 106).

4 The mean number of children born alive per ever married woman aged 45+ varied between 4.0 in status I to 5.1 in status III in rural areas and from 5.0 in professional class to 5. 6 in upper white collar class to 5.0 in the lowever white collar class. See *Mysore Population Study* op. cit p. 125.

5 Swaroop S. and Uemura, K. "Proportional Mortality of 50 years and above" *Bulletin of the World Health Organization*, Vol. 17 No. 3, 1957, p. 456.

6 Vaidyanathan K. E. "A Simple Method for estimation of death rate and expectancy of life from defective death registration statistics" (Unpublished)

7 United Nations, *Determinants and consequences ... op cit* p. 62.

8 India, National Sample Survey No. 177 (19th round) *Vital Rates in India July 1964—65*

9 Council for Social Development, Hyderabad, *The Shadnagar Standard Fertility Survey: Interim Report* 1971.

10 Examples of such studies are the studies of the Registrar General in England and those of the Metropolitan Life Insurance Co. and National Tuberculosis Association in the United States. See Logan W. P. D. "Social class Variations in Mortality" *Public Health Report 69*: 1217—1223, Dec. 1954; Dublin L. I. "Causes of Death by occupation" *U. S. Bureau of Labour Statistics Bulletin* No. 7 U. S. Govt. Printing Office Washington DC 1917.

11 D. N. Saxena, *Social Context of Fertility and Family Planning 1972* (in press) Chapter III.

On Ascertaining the Causes of Death in Rural India*

V. K. Ramabhadran and Brijesh B. Lal

Introduction

It is well known that medical services in the rural areas of India are inadequate. Whatever statistics on causes of death are available have been collected under eight or nine causes and are published annually in the *Vital Statistics of India* by the Registrar General. A knowledge of the prevailing morbidity and mortality pattern is but absolutely necessary for the framing of public health programmes and for appraising their impact on the community. In India, as in many other developing countries, the quality of statistics of causes of death collected through the lay reporting system does not permit a proper delineation of public health programmes[1] because of the crude nature and poor quality of statistics. With a view, therefore, to facilitate the growth and expansion in the country of health and medical services and of the health registration system at large, the Registrar General, India launched the Model Registration Scheme.

Some of the basic features in obtaining vital and health records through lay reporting are the following:

i) The person assigned this job should be familier with the local community or should be a resident of that area;

ii) He has to be provided with a convenient method of recording relevant events and the circumstances of death. For this some

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* This is an analysis based on the Model Registration Scheme undertaken by the Registrar General, India.

inducement may have to be offered to him to obtain regular reports; and

iii) Being a layman he should be duly trained in the methodology of identifying the causes of death through a simple method of questioning the household of the deceased.

The Model Registration Scheme

The Scheme of Model Registration aims at ascertaining the causes of death by para-medical personnel stationed at selected primary (rural) health centres in the country. The data are collected through a field agent, usually s sanitary inspector, health visitor or other para-medical person, who obtains information about the occurrence of deaths from fixed locally resident informants and then contacts the household to obtain particulars in accordance with the procedure laid down for the non-medical list ("NM List"). The NM List does not attempt to assign specific causes but limits itself to indicating the broad symptoms and conditions of the diseases, It is a contrivance to obtain some numerical data, which combined with sex and age factors can enable the health administration to have a qualitative knowledge of locally prevailing diseases at different seasons and local habits and customs, and to form an idea of the health conditions and needs of the population concerned for initiating health programmes. It may not yield the incidence of specific diseases, but identify conditions which call for special attention by the local health authorities. The non-medical list is so drawn that with the information about the symptoms, conditions, anomical site and duration of disease, it should be possible to fix the probable cause of death. Further, at the end of each quarter or if that is not possible every half-year, a house-to-house visit is made and the findings are matched with the entries in the register maintained by the field agent to update the information. The Medical Officer-in-Charge of the primary health centre checks the causes of death in respect of 10 per cent of recorded deaths. This serves the purpose of assessing whether the investigation conducted by the field agent does or does not bring out the probable causes of death. The purpose of obtaining such data should not be construed to mean the replacement of proper medical certification of cause of death.

In essence, therefore, the Model Registration Scheme seeks to provide mortality statistics by surveying the cause of death through para-medical personnel at the primary health centre level so that after carefully viewing the pattern of diseases prevalent under the local conditions of the areas concerned, remedial and preventive measures could be taken. The Scheme could also be utilised to evaluate specific public health programmes or projects which might have been introduced in these selected areas. On the basis of the number of deaths reported against various causes over a period of time, an idea can be had of the success of a programme for eradicating or for limiting a particular disease.

The present reduction in mortality can to some extent be ascribed to specific programmes for control of diseases rather than for overall socio-economic development. The decline of mortality in India after the Second World War has resulted mainly from India's participation in the WHO Programmes for Control and Eradication of Malaria, Small-pox, Plague and Cholera through vector control and mass immunisation. While various estimates of death rate in India have been made, it is clear from the figures (whatever be the correct level), that mortality has definitely been declining According to official estimates, the overall death rate in India during the 30 years period of 1921—50 was 30.1 per 1000 and the average for the decade 1941—50 has been estimated officially at 27.4 per 1000 population[2]. Coale and Hoover estimated the rate to be 30.9 per 1,000 for the latter period[3]. The death rates for rural India estimated from the National Sample Survey data have also shown a decline from 24.0 in 1953—54 to 21.0 in 1955—56 and to 19.0 in 1958—59[4]. The Census of India 1961 estimated the death rate as 22.8 per 1000. According to the Scheme of Sample Registration of Births and Deaths, the death rate in rural India is estimated at 16.8 per 1000 in 1968 and 19.1 in 1969. These estimates are only approximations and have been cited here to establish not the levels of mortality but the fact that in India the mortality rate has definitely declined. The control of infectious diseases has been found to have played a leading part in bringing about this decline.

About the Data

As mentioned earlier, the data pertain to the selected rural areas covered in the various states in India under the Model Registration Scheme during the years 1966 through 1969. Until 1967 besides the Headquarters village of the primary health centres, one or two adjacent villages were also covered. Since 1968, however, some of the states reported figures for the Headquarter villages only while others sent in data for the larger number of units. In 1969, all the states switched over to the Headquarter villages except Mysore which continued to report for the earlier 234 units as well. Rajasthan data had been included upto November 1969 only. The coverage of area should, however, not weigh much in a survey of cause of death since the aim is not to produce the rates. · Nevertheless, the number of events has to be sufficiently large so that an analysis of the causes of death could be meaningful. A total of 16,400 deaths in 1966, 21, 472 in 1967, 19,160 in 1968 and 20,964 in 1969 have been reported. Data for 1966, 1967 and 1968 have already been published in greater details; that for 1969 are in the Press. Out of these total number of deaths, tables have been prepared to highlight mortality of infants and of mothers which play a decisive role in determining the overall mortality rate.

General Mortality Pattern

Table 1 presents the distribution of deaths by major cause groups and also by age and sex for rural India for 1969. The table may be viewed from two angles—one as percentage of deaths within each age group by cause of death and secondly as percentage of deaths for each cause of death by age group. Considering the age groups first, it may be noted that the largest number of deaths amongst infants (0—1 years) have occurred on account of disease of infants. Cough and fevers have occurred for over 30 per cent of infant deaths. Children between ages 1—4 and 5—14 have been reported to be more susceptible to fevers of various kinds as compared to diseases relating to cough. The pattern for age group 15—34 is also more or less the same though the intensity of fevers and cough diseases was more or less equal. The figures for age groups 34—54 and 55 + however, show that again diseases relating to cough are more pronounced than fevers or swellings.

Table 1

PERCENTAGE DISTRIBUTION OF DEATHS BY MAJOR CAUSE GROUPS AND AGE - ALL INDIA (RURAL) 1969

Code No.	Cause and / or Prominent Symptoms	MALE .0–1	.1–4	.5–14	.15-34	.35-54.	55+	.Total	FEMALE .0–1	.1–4	.5–14	.15-34	.35-54.	55+	.Total
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	A. Percentages by age groups														
1.	Violence or Injury	1.8	6.8	21.0	33.6	23.0	13.8	100.0	3.4	8.9	16.0	35.2	19.8	16.7	100.0
2.	Child birth & complicated Pregnancy	—	—	—	—	—	—	—	—	—	—	74.3	25.7	—	100.0
3.	Diarrhoea	17.0	30.3	12.1	7.4	11.1	22.1	100.0	16.1	32.5	12.3	8.6	8.7	21.8	100.0
4.	Cough	15.4	15.2	4.5	6.1	16.7	42.1	100.0	17.2	21.8	6.1	8.8	13.9	32.9	100.0
5.	Swellings	2.4	8.3	5.2	10.2	24.7	49.2	100.0	3.1	13.4	5.1	11.0	21.8	45.6	100.0
6.	Fevers	11.7	29.0	12.9	10.1	13.1	23.2	100.0	13.1	30.3	13.8	10.6	11.9	20.3	100.0
7.	Other Infant Deaths	100.0	—	—	—	—	—	100.0	100.0	—	—	—	—	—	100.0
8.	Other Clear Symptoms	25.6	8.3	5.6	6.2	14.1	40.2	100.0	32.6	8.8	4.6	9.3	13.4	31.3	100.0
9.	Extreme old age and Others	2.3	10.2	2.1	3.9	6.3	75.2	100.0	2.5	12.3	3.0	5.1	4.3	72.8	100.0
	Total	21.4	15.4	6.6	7.4	12.7	36.5	100.0	21.2	18.5	7.2	10.4	10.9	31.8	100.0
	B. Percentages by Cause groupss														
1.	Violence or Injury	0.3	1.7	12.5	18.1	7.2	1.5	3.9	0.5	1.4	6.7	10.1	5.5	1.6	3.0
2.	Child birth & complicated Pregnancy	—	—	—	—	—	—	—	—	—	—	20.2	6.7	—	2.8
3.	Diarrhoea	7.0	17.4	16.0	8.9	7.7	5.3	8.8	7.3	16.9	16.5	8.0	7.7	6.6	9.7
4.	Cough	19.1	26.2	17.7	21.7	34.8	30.4	26.4	18.2	26.4	19.0	18.9	28.7	22.7	22.4
5.	Swellings	00.9	4.5	6.5	11.5	16.1	11.1	8.3	1.1	5.5	5.4	8.0	15.1	10.8	7.6
6.	Fevers	10.6	36.6	37.6	26.5	20.0	12.3	19.4	13.6	36.0	42.4	22.3	24.0	14.0	21.9
7.	Other Infant Deaths	53.6	—	—	—	—	—	11.5	50.4	—	—	—	—	—	10.7
8.	Other Clear Symptoms	6.7	3.0	4.7	4.7	6.2	6.2	5.6	6.8	2.1	2.8	3.9	5.4	4.3	4.4
9.	Extreme Old age and others	1.8	10.6	5.0	8.6	8.0	33.2	16.1	2.1	11.7	7.2	8.6	6.9	40.0	17.5
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Looking at the total picture, it may be observed that around 25 per cent of deaths have occurred due to diseases of cough, followed closely by the various kinds of fevers which accounted for over 20 per cent of the cases. By viewing the table for each cause through the various age groups, it would be observed that violence and injury has accounted for about 56 per cent of deaths for persons between 15—54 years of age, of which 34 per cent occurred to young adults in the age group 15—34. Most of the deaths due to puerperal causes (74.3) have occurred to women in the age group 15 to 34 representing that the risk to life of mothers in these ages was three times greater than to mothers aged 35—54. More than 31 per cent of deaths due to diarrhoea were reported for children in the age group 1—4 and about 17 per cent in the age group 0—1. Diseases involving cough, as expected, were more pronounced in the older age groups where about 38 per cent of all deaths due to this cause occurred to persons aged 55 and over. Chart I shows a more or less stable picture of these percentages by causes except perhaps the percentage of deaths due to extreme old age which shows a rising trend.

Maternal Deaths:

Table 2 and chart II show the percentage of maternal deaths due to puerperal causes during the four years 1966 to 1969. The number of deaths due to maternal causes has shown a slight decrease during these years. In terms of percentage to total deaths the figure has dropped from 1.5 in 1966 to 1.3 in 1968 and remained at that level in 1969. Amongst all the puerperal causes the more important causes have been Puerperal Sepsis, Post Partum Haemorrhage, Anaemia of Pregnancy and Eclampsia. The first place until 1968 was taken by puerperal sepsis which accounted for more than 16 per cent of all maternal deaths. In 1969 however, it ranked third with 13.0 per cent after Post Partum Haemorrhage (15.9 per cent). Two other trends in maternal deaths may also be noticed. Abortion as a cause of maternal death has shown a steady increase since 1967. The level has risen from 7.5 per cent in 1967 to 9.8 per cent in 1969. Part of this increase may be ascribed to the liberalisation of abortion laws. The number of fatal cases seems to have increased with the possible increase in the number of abortions. Similarly, Post Partum

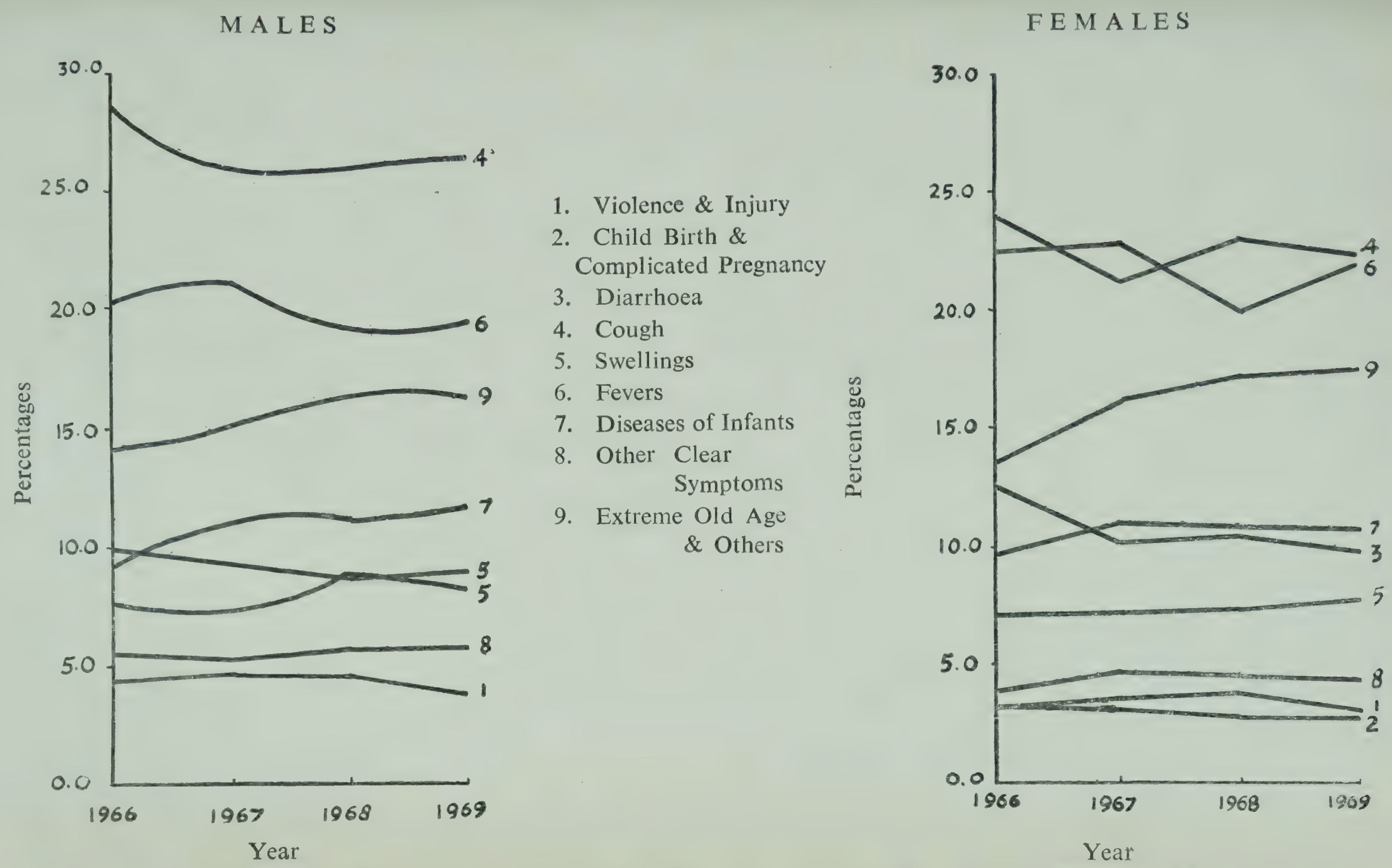

Chart 1: *Trends in percentages of total deaths by causes 1966 — 1969*

Table 2

DISTRIBUTION OF MATERNAL DEATHS BY PUERPERAL CAUSES FOR RURAL INDIA 1966–69

No.	Causes	1966		1967		1968		1969	
		No. of deaths	Percentage	No. of deaths	Percentage	No. of deaths	Percentage	No. of deaths	Percentage
1	2	3	4	5	6	7	8	9	10
1.	Abortion	26	10.7	23	7.5	24	9.8	27	9.8
2.	Eclampsia	34	14.0	36	11.7	30	12.2	21	7.6
3.	Placenta Praevia	5	2.1	15	4.9	21	8.5	20	7.3
4.	Haemorrhage in delivery	24	9.9	33	10.7	22	8.9	20	7.3
5.	Post Partum Haemo-rrhage	38	15.6	35	11.4	31	13.8	44	15.9
6.	Anaemia of pregnancy	33	13.6	48	15.7	31	12.6	41	14.8
7.	Abnormal presentation	8	3.3	20	6.5	14	5.7	8	2.9
8.	Puerperal Sepsis	46	18.9	51	16.6	42	17.1	36	13.0
9.	Not Classifiable	29	11.9	46	15.0	28	11.4	59	21.4
	Total	243	100.0	307	100.0	246	100.0	276	100.0
	Total maternal Deaths as percentage of total deaths		1.5		1.4		1.3		1.3

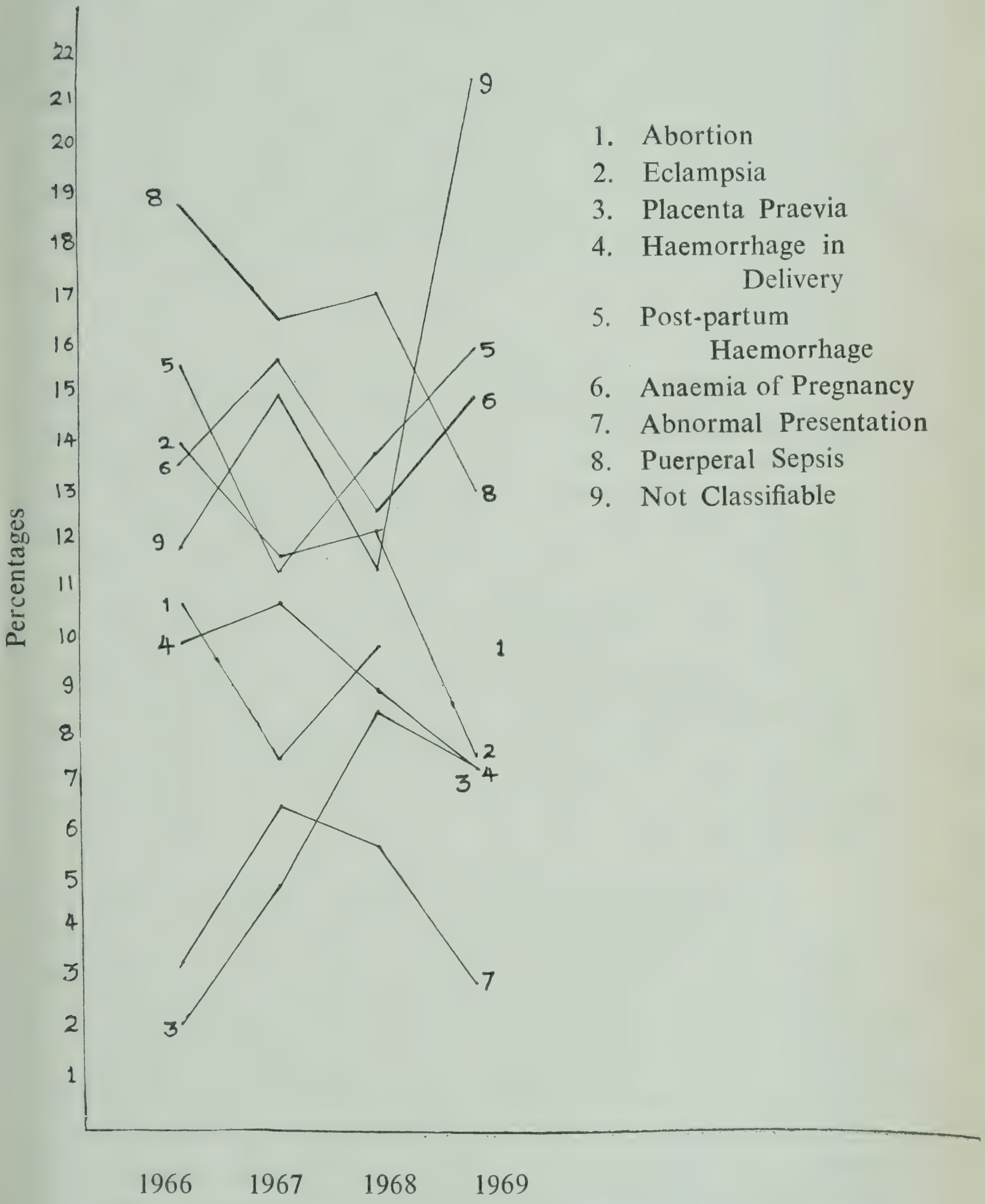

Chart 2: *Trends in percentage of maternal deaths by causes*

Haemorrhage has shown a continuous rise from 11.4 per cent in 1967 to 15.9 per cent in 1969. Throughout the period deaths due to Anaemia of Pregnancy have amounted to about 15 per cent. Eclampsia claimed much fewer deaths totalling upto 7.6 per cent in 1969 as compared to 14.0 of 1966. Further, it may be noted that a considerable number of maternal deaths could not be classified into any of the categories mentioned in the table with the result that a sizeable number (21.4 per cent of maternal deaths) remained unclassified in 1969. To some extent, this might reflect the difficulty of the field agent in eliciting proper response from the respondents.

Infant Deaths:

In Table 3 important causes of infant deaths have been shown. These include violence and injury, dysentery and diarrhoea, cough, swellings, fevers, diseases of infants and other clear symptoms besides the residual category. To begin with, it may be noted that there is a decrease in the percentage of infant deaths to total deaths over the years 1967 to 1969. In 1967, 24.1 per cent of all deaths occurred to infants. The figure declined to 21.3 per cent in 1969. The slight rise in percentage in 1967 over 1966 seems fortuitous in the context of continued expansion and spread of programmes for prenatal and post natal care of mothers and also for the control of infective and parasitic diseases through the use of antibiotics, The decline in the above proportion from 1967 to 1969 should indicate the suceess of the schemes for providing medical attendance to mothers and the new born.

The most important causes of infant deaths in 1969 are broncho-pneumonia and pneumonia, (17.2 per cent of all infant deaths), diseases peculiar to infancy (13.6 per cent), prematurity (12.7 per cent) unclassifiable causes (10.6 per cent) and dysentery and diarrhoea (7 per cent). If the causes are grouped according to symptoms (not shown in Table 3), it would appear that diseases of infants (52 per cent) cough (19 per cent) and fevers (12 per cent) are the most important causes of infant deaths in rural India. The unclassifiable causes constitute one-tenth of total infant deaths, which indicates the difficulties in identifying causes of infant deaths in rural areas.

Table 3

DISTRIBUTION OF INFANT DEATHS BY CAUSES FOR INDIA (RURAL) 1966-69

Sl. No.	Causes	1966		1967		1968		1969	
		No. of deaths	Percentage	No. of deaths	Percentage	No. of deaths	Percentage	No. of deaths	Percentage
1.	Violence & Injury	20	0.5	26	0.4	16	0.4	18	0.4
2.	Dysentery	317	8.2	301	5.8	239	5.6	211	4.7
3.	Broncho-Pneumonia and Pneumonia	805	20.8	978	18.9	782	18.2	769	17.2
4.	Swellings	36	0.9	58	1.1	36	0.8	45	1.0
5.	Typhoid	88	2.3	105	1.0	—	—	—	—
6.	Measles	68	1.8	105	2.0	36	0.8	84	1.0
7.	Diphtheria	12	0.3	26	0.5	73	1.7	38	0.8
8.	Birth Injuries	88	2.3	157	3.0	132	3.1	110	2.5
9.	Cyanosis	95	2.4	146	2.8	145	3.4	183	4.1
10.	Infection of new born	292	7.5	372	7.2	259	6.0	346	7.7
11.	Prematurity	336	8.7	501	9.7	505	11 8	566	12.7
12.	Diseases peculiar to infancy	419	10.8	587	11.4	551	12.8	609	13.6
13.	Infant deaths, not classifiable as above	286	7.4	546	10.6	468	10.9	417	9.3
14.	Tetanus	179	4.6	272	5.3	304	7.1	290	6.5
15.	Unclassified causes and the rest	555	14.3	536	10.4	390	9.1	472	10.6
	Total Infant deaths	3878		5165		4291		4462	
	Total deaths	16 400		21 472		19 160		20 964	
	Percentage of Infant deaths to total deaths	23.6		24.1		22.4		21.3	

Note: Causes of Infant deaths accounting for less than 2.0 per cent cases have not been included in this table. The total shown for infant deaths may therefore not tally with the sum of the 15 causes.

Looking at the absolute and relative trends (Table 3 and Chart III), it may be noticed that the number of infant deaths due to dysentery, broncho-pneumonia, typhoid and unclassifiable causes have declined, whereas the number of deaths due to diseases peculiar to infancy, prematurity, diptheria, tetanus, cynosis and measles have shown a rise. Broncho-pneumonia accounts for 17.2 per cent of infant deaths in 1969 as against 20.8 per cent in 1966, and still continues to be the leading cause of infant death. The relative increase in the number of infant deaths due to prematurity is indeed surprising in the context of the expansion of prenatal care that has taken place in the rural areas. Perhaps this may be due to an improvement in diagnosis rather than a real increase in the number of infant deaths due to this cause. Similarly, the increase in the number of deaths due to tetanus is also surprising as the introduction of triple vaccine a few years ago was expected to bring about a reduction in the number of infant deaths due to this cause. Infections of the new-born have continued to claim around 7 to 8 per cent of infant lives indicating that there is scope for improving post-natal care and the nutritional level of infants in rural areas.

Conclusion

The Model Registration Scheme is a major effort of the Office of the Registrar Gneral to identify causes of death in rural areas through the para-medical staff of the primary health centers in selected areas of the country. The causes of deaths are determined from information about symptoms, conditions, anomical site and duration of disease. It appears that the scheme has helped in the more accurate identification of causes of deaths. Nevertheless there are still about 10 per cent of maternal and infant deaths and over 15 per cent of all deaths whose cause of death is shown as unclassifiable. There is considerable scope for improvement of the scheme through better training of para-medical personnel, a greater elaboration of different causes of deaths and their symptoms, better supervision by medical personnel, and the appropriate incentives for efficient work.

The data presented in the paper show that in the case of all deaths the causes identified as cough and fevers have occupied prominent places. There is considerable stability in the proportion

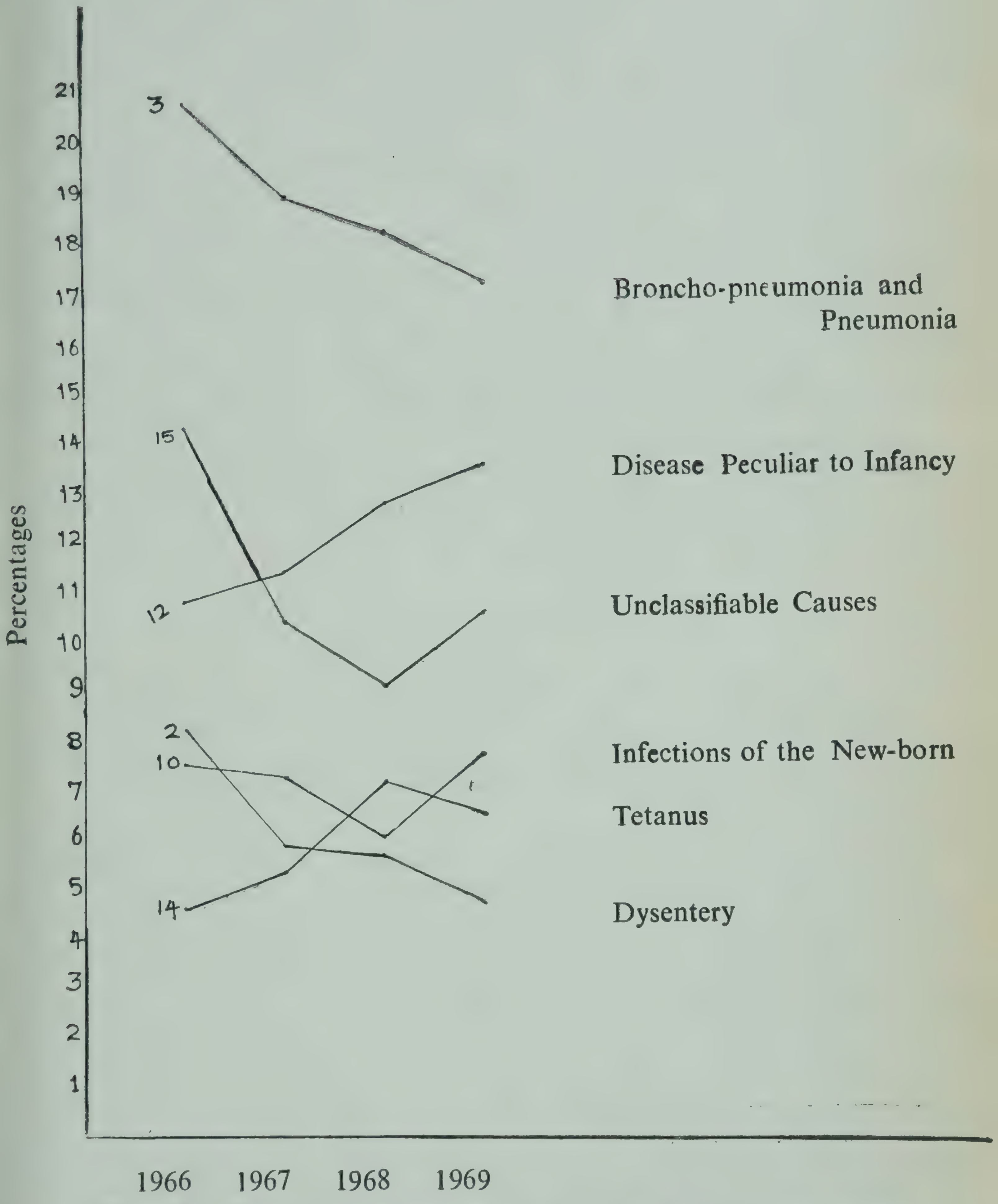

Chart 3: *Trends in percentage of infant deaths due to some major causes 1966—1969*

of deaths due to different causes over the period under review. Among the important causes of maternal mortality, puerperal sepsis, post-partum haemorrhage, anaemia of pregnancy and eclampsia are responsible for the highest number of deaths in that order. There is a decline in the proportion of maternal deaths due to puerperal sepsis and eclampsia, while there is a rise in the proportion of maternal deaths due to unclassifiable causes. The important causes of deaths of infants have been found to be cough diseases, the prominant being pneumonia and broncho-pneumonia. Other major causes of infant deaths are diseases peculiar to infancy, prematurity and unclassifiable causes. It is noticed that the proportion of infant deaths due to dysentery, broncho-pneumonia, typhoid and unclassifiable causes have declined, whereas those due to diseases peculiar to infancy, prematurity, diphtheria, tetanus, cynosis and measles have increased. This shows that although success has been achieved in reducing the mortality due to some of the controllable causes, there is considerable scope for improving the sanitation and nutritional levels of infants in rural areas in order to effect a reduction in mortality due to 'hard core' causes.

NOTES

1 Model Registration Survey of Cause of Death, Manual of Instructions, Part I, Organisation, Foreward, Office of the Registrar General, India.

2 Census of India, "Estimation of Birth and Death Rates," Paper No. 6, 1954.

3 A. J. Coale and E.M. Hoover, *Population Growth and Economic Development in the Low-Income Countries* (Princeton, N.J. 1956) pp. 29-54.

4 National Sample Survey, *Preliminary Estimates of Births and Death Rates and of the Rates of Growth of Population, 14th Round, July, 1958-July, 1959, No. 36,* Calcutta March, 1960 p. 9.

Analytical Mortality Studies

Mortality and Longevity in India During 1901—1961

Kumudini Dandekar

In the census of 1971, the enumerated population fell short of population-size expected by the experts. The experts forming a committee for population projections in 1964, had forecast a population of 560 million while the actual population count in 1971 is 547 million for India. The forecast was based on certain assumptions regarding birth and death rates and a decline in them. A smaller population than expected either suggests more decline in birth rate or less decline in death rate than the experts believed since population of India is a closed population. This, of course, is on the assumption of the same level of enumeration in the censuses of 1961 and 1971. Skepticism regarding India's capacity to reduce its birth rate leads some quarters to be pessimistic; they believe in less-than-expected decline in death rate as the plausible explanation for the difference in the census count and expected population. The present article sketches the implications of such an explanation after a review of the mortality conditions in India during the twentieth century.

Assessment of mortality conditions in India is based exclusively on the population counted for various age years at the censuses. Thus for the country as a whole the number aged 40 years at a census are regarded as survivors of those aged 30 years at the previous census, conducted a decade ago. Such procedure determines the death rate for various age groups during a decade between the two censuses. Every census has a set of age-specific mortality rates given in a table called the census life-table. The total dependence on the census life-tables for mortality assessment in India is due to:

(a) Vital registration in India is not dependable.

(b) For any empirical observation regarding mortality, the size of the sample needed for a given level of precision in measurement

is large and costly because of variability in conditions with wide range of varying cultures and physical conditions.

(c) There is faith in the near-completeness of enumeration at the census. This is due partly to the vastness of the whole census affair.

(d) Assumption of the same level of under or overenumeration at the two consecutive censuses leaves the census life-table comparatively undisturbed.

(e) There is no other go.

The census life-tables commanded faith more for the ingenuity they required for their construction rather than for their reliability. Though highly technical, the construction was based on nothing reliable. The completeness of enumeration was doubted. The uncertainty due to this was often alleviated by the assumption of the same level of underenumeration in the two consecutive censuses. The basis for this was more often the ignorance than any sound reasoning. The reported ages have rarely been worthy of reliance. Epidemics and famines upto 1921 always shattered the basis of any respectable guesses. The differential coverage from census, to census, if any, could rarely be assessed or corrected for. All these factors resulted in census life-tables with unknown precision. Their assessment needed a long-term as well as a short-term view. The short-term view was provided by the census actuary with his closeness to the census operations. As a technician, he always assured himself of the consistency of the life-tables with other demographic observations. However a long-term view could hardly be had because of the stagnancy of mortality conditions at a level never observable in modern times for countries with reliable data. A time has perhaps come when a long-term review can be had with great advantage in construction of the life-table. More recently, i. e. since 1951, a critical appraisal of the census data from a variety of approaches paved tbe way for a long-term assessment of morality and longevity in India.

The census life-tables have a hundred-year history in this country. The decades upto 1921 were intermittently in the grip of famines and epidemics which affected mortality levels and hence the

longevity of the Indians In 1881 or 1891 it was about 25 years of life. But in the intervening decades it deteriorated by about 3 or more years. The longevity or expectation of life for a man or woman born in India was as shown below for the various census years :

Census year	Male longevity	Female longevity
1881	23.7	25.6
1891	24.6	25.5
1901	23.6	24.0
1911	22.6	23.3
*1921	19.4	20.9
1931	26.9	26.6
*1941	32.1	31.4
1951	32.5 (33.5)**	31.7 (34.7)**
1961	41.9 (44.2)**	40.6 (45.7)**

* No census life-tables were constructed for these years. K. Davis constructed them in his book *'Population of India and Pakistan.'*

** The bracketed figures are estimates by Coale and Hoover.

The mortality conditions for the various census years before 1931 fluctuated erratically due to varying impact of the natural calamities on the two sexes and the various age-groups. The pictures of mortality conditions by the census actuaries constructing life-tables depended as stated before, on their impressions regarding the well-being of various age-groups in the preceding decade. This was because of the need to correct the age reporting in the censuses. Methods of correction changed from census to census. It is intended to record below the peculiarities of the mortality pattern depicted by the Indian life-tables.

Greater Longevity of Indian Females than Males before 1931 But Not Later

The greater longevity of females upto 1921 observed in the above table may be the effect of construction of the life-table on the basis of greater longevity of females observed in other parts of the world for all times and regions. This is not observed for the censuses in India from 1931 on. We may consider two possible hypotheses. One is that the Indian female did have an advantage over the male

before 1931. But the conditions deteriorated later in favour of males though they improved the longevity of both. Such a hypothesis upsets our impressions regarding the status of females vis-a-vis the males.

The other hypothesis is that the earlier life-tables may have to be revised for the proper sex-differentials observed in later censuses on the basis of assumed differential underenumeration in the two sexes. In this revision one has to bear in mind that the sex-ratio for the various census years during the last 70 (or hundred) years shows deteriorating numbers of females compared to males. The trend is so consistent and regular that one believes in it. But its interaction with the two hypothesis stated above leaves one in a perplexing situation. An explanation can be looked for, into (a) differential underenumeration for the two sexes (b) different level of underenumeration from one census to the other. It may be possible to construct relative differences in levels of underenumeration in the censuses on certain plausible assumptions such as :

(a) The health conditions of women relative to men are at least not deteriorating in the successive years.

(b) The levels of enumeration improve with better communications. For the same mortality conditions, this will show better survival for the successive censuses, if communications have improved successively in the later censuses.

(c) The relative levels of enumeration of males and females have differed and these are mainly responsible for the sex differentials observed in the longevity in the census life-table.

It is not proposed to apply the above criteria and come out with estimates of relative underenumeration in the censuses in the present article. The idea in mentioning the above possibilities is to bear in mind the factor of differential underenumeration, so important in the construction of life-table. When blocks of areas with their population are missed, this administrative inefficiency may affect the enumerations. But it is often for both the sexes. Differential enumeration in sexes is caused by different factors. The reasons behind such underenumeration are likely to be cultural. For instance, the desire to report or not, a male or female. These being

deeply embedded in the fabric of the society cannot be easily brought to the surface. A critical appraisal of the kind stated above may help fathoming such factors. The difference in longevity of males and females is about +2 years in the earlier decades and −1 year in the later decades. It may seem small. But the expectation is that the sign also must change. In the present situation one has to decide on two years' difference in longevity of females for only 24 years' of males. This involves the questionability of more than 8 per cent female life. One can clearly see the importance of thrashing out the problem.

Gain in Longevity in the Successive Censuses

There was no addition to longevity during the course of 50 years since 1872. If at all, there seemed deterioration of mortality conditions with erratic impact of famines and epidemics. One peculiarity of the census life-tables upto 1921 was that the impact of good or bad times in those days affected most the mortality in the age group 10 to 29 years or so. This will have to be borne in mind especially when one discusses the mortality pattern and change in it in the later censuses.

Compared to past better-year average longevities, there was an addition to them of about 3 years during the decade 1921–31. This was supposedly the first decade in the Indian region completely free of famines or epidemics in the present century. One took for granted this addition to longevity. But the addition of about 5 years during 1931–41 by the life-table (by K. Davis) for 1941* cannot be easily explained after a review of life-tables in the successive decades. For instance, the performance in the decade 1941-51 seems unexpectedly dull when compared with 1931-41. This may be the result of judgements in constructing the life-tables for the two decades. One is therefore tempted to leave out either 1941 or 1951 life-table as 'not in line with' other census life-tables. One may assume that about 6 years of life was added during 1931-51 and probably there is no disagreement on the point.

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* The 1941 census had no life-table. Hence K. Davis constructed it. It does not fit in properly with the life-tables constructed by the census actuaries. It is a typical example of how the construction of life-table is moulded by judgements.

During 1951-1961, more than nine years' longevity was added to human life in India. Besides the census estimate of the life-table, other estimates such as those of Coale and Hoover were made not only for 1951 but for later years. Coale and Hoover estimates announced slightly higher longevities than those by the census for 1951 as well as 1961. Besides, they insisted on a higher longevity for females than for males as observed in the rest of the world, implying an underenumeration of females in the Indian censuses relative to males. The discrepancies between the census life-tables and those by Coale and Hoover, (or any set of model life-tables such as those by the United Nations, or Coale and Demeny) can be discussed by analysing the mortality pattern in India for various age groups. The need for such an analysis arises due to the need for higher precision in mortality measurement stated in the next paragraph.

From 1951 on, there is a special interest in the census life-tables. Besides the interest in the life-tables per se, the impact of death-decline on the population growth has to be distinguished from the impact of decline in birth rate. This enhances the desire to measure birth and death rates with precision. Unfortunately one has still to rely on census enumerations to get trustworthy figures for both. The error in one direction or the other throws people into pessimism or optimism and one has to wait for another decade and a census to revise one's impressions with confidence. 1971 census is a good example of this conflict in the pessimistic and optimistic attitudes and it puts to test the capabilities of modern demographers at precision of measurement.

Lower Mortality in Infancy in India Than Elsewhere

For any given level of longevity the death rate for the age group 0-4 years is smaller in Indian life-tables of all times upto 1961. A comparatively higher death rate for age 5-9 years does not make up for the higher mortality in age group 0-4 years observed in any other life-tables, such as those by Coale and Hoover, Coale and Demeny or the United Nations. The other peculiarity is the higher death rate in the Indian life-tables upto age 30 than elsewhere for the age period 10-29 years for the same longevity levels. If the Indian situation is to be relied upon, what possibly could be an explanation?

One has to look into the cultural set up of India for an explanation. One possibility seems to be the long duration of

breast-feeding observed in India. With long duration of breast-feeding the Indian babies (male and female) are possibly less exposed to external hygiene and the hazards accompanying low levels of nutrition. Hence the age group 0-4 years may be more secure in India than elsewhere for the same level of longevity. On the other hand, the earlier half of adulthood of women may be more insecure in India for the same reason i.e. constant erosion of calcium through breast-feeding without any help from nutrition. As for adult males, their relatively higher death rate in earlier half of adulthood compared to that found elsewhere (for the same longevity) may be due to low levels of living and nutrition.

In case the above explanation for the observed pattern of mortality is not acceptable, the other alternative is to revise the Indian life-tables to conform to the pattern observed elsewhere. The only part of the life-tables which is not based on actual observations is the earliest age group 0-4 years. If it was to be brought in line with the death rates for later age years, the resulting Indian longevity will have to be revised and it will be reduced appreciably. This will upset the consistency of the life-tables with other demographic set-up of the census with its birth and death rates. The other possibility is to revise smoothing procedure for age group 10-29 years.

Change in the Observed Pattern of Mortality During 1951-61

A comparison of the three sets of life-tables (namely Indian Census life-tables, U.N. Model life-tables, Coale and Demeny life-tables) consistently brought out the peculiar features of Indian mortality discussed above. However, the census life-table for 1961 seemed to alter the earlier pattern. The age-group-specific mortality rates for the census life-tables were of course lower as usual for age group 0-4. But they were lower for the census also for the age groups upto 30 after which they rose higher. It seemed that the pattern of death rates for the age group 10-29 for India in 1961 was the same as that indicated by Coale and Hoover. But this was for a higher longevity with Coale and Hoover. Thus it is worth while comparing the improvements in mortality till 1951 and 1961 to bring out the change in the pattern. This is done below.

Indices of improvement in mortality in 1951 and 1961 were constructed with 1911 and 1931 as bases. The use of 1911 as base

was because the decade 1901—11 was comparatively free of famines and epidemics. The use of 1931 was suggested for the same reason besides its smooth age distribution based on different considerations. These are presented for males and females in the Tables A and B. The tables show that with 1911 as base year the mortality rate for age group 0-4 years of males was only 67 per cent in 1951 and 50 per cent in 1961. The improvement was thus 33 and 50 per cent respectively upto 1951 and 1961. On the other hand for age group 5—19, the improvement was less than 20 per cent in 1951 but 66 per cent in 1961 as compared to 1911. Similar trend is observable for ages upto 39 for males and upto 29 for females.

Table A

MORTALITY INDEX, 1911–1961, INDIA

Age	Males						Females					
Group	1911	1921	1931	1941	1951	1961	1911	1921	1931	1941	1951	1961
0 – 4	100	109	89	79	67	50	100	102	86	77	74	52
5 – 9	100	96	67	54	81*	34	100	85	60	50	92*	42
10 – 19	100	150	73	75*	83*	34	100	158	86	93*	70	36
20 – 29	100	127	78	65	62	33	100	132	107	81	59	38
30 – 39	100	113	88	62	64	47	100	119	109	77	80	71
40 – 49	100	105	94	59	71	66	100	127	108	76	80	76
50 – 59	100	101	97	72	88	80	100	104	100	77	83	80
60 – 69	100	98	97	75	101	88	100	92	93	74	92	81
70 +	100	100	100	100	100	100	100	100	100	100	100	100

* Doubtful pattern of improvement in mortality.

Table B

MORTALITY INDEX, 1931–1961, INDIA

Age	Males				Females			
Group	1931	1941	1951	1961	1931	1941	1951	1961
0 – 4	100	89	75	56	100	90	86	66
5 – 9	100	81	121*	50	100	82	153*	69
10 – 19	100	107*	114*	46	100	109*	81	42
20 – 29	100	83	80	43	100	76	56	36
30 – 39	100	71	73	54	100	70	74	65
40 – 49	100	67	75	70	100	70	74	70
50 – 59	100	71	90	82	100	77	83	80
60 – 69	100	77	104	90	100	80	99	87
70 +	100	100	100	100	100	100	100	100

* Doubtful pattern of improvement in mortality.

With 1931 as base year one observes similar pattern of improvement in 1961 and 1951 as observed above except for the age group 5-19 for males and 5-9 for females in 1951 when the conditions seemed to deteriorate. The similarity means an exceptional improvement in the age period 10-39 or so in 1961. An explanation for the deterioration of conditions for certain age groups observed in 1951 has to be sought in the smoothing procedures or underenumerations. Correcting them in one direction or the other may have far-reaching effects. However, while using 1931 as the base, 1941 pattern of improvement does not seem inconsistent and one wonders whether one should accept 1941 or 1951 pattern.

The effect of the above was that with a specific gain in overall longevity, the addition in longevity due to improvement in mortality of age group 0-4 though higher than in any other age group of similar size, was much smaller compared to additions observed elsewhere. For instance with 15 years added to Indian longevity during 1931-61, only 5 were added by improvement before age 5 and the rest spread over the whole age span. Could it be possible that the relative improvements in mortality in age group 0-4 were also put away because of its being protected with breast-feeding?

The implications of the pattern of improvement in mortality may be interpreted as under.

The Indian pattern of mortality from 1921-1951 perhaps reflects what improvement could occur in a poor, tropical, big country by cessation of epidemics with certain cheap preventive measures and perhaps a little improvement in hygiene. It also reflects the cessation of famines with improved communication facilities. But the mortality improvement in 1951-61 reflects the reactions of the country to modern medical facilities at low levels of living including the preventive measures such as the use of DDT. BCG, or the use of curative drugs such as sulphadrugs, etc. The living conditions in India may not have appreciably changed to effect improvement in the ever-handicapped early working age upto 30 years. But the control of malaria and similar disabling diseases perhaps helped these ages. To have further improvement above age 30, perhaps a change in the living conditions is necessary. Further, the breast-feeding may

protect babies in their infancy at very low levels of longevity. But the same may keep away improvments in it at slightly higher longevities.

The experience of no country in the world seems closer to India than that of Ceylon and still Ceylon had more than 62 years of longevity in 1963. However, it had about 47 years' longevity in 1947. Though the living conditions are different in the two countries, the cultural set-up is very much the same. For various reasons the reliability of vital data for that country is likely to be high. The pattern of improvement in mortality in Ceylon during 1901 - 1947 can be compared to India during 1911-1941, though India had a smaller longevity. There are two possible patterns of improvement in Indian mortality which may go with Ceylonese pattern of 1945-47. One is the 1941 pattern and the other 1951 pattern. One does not know which pattern to choose for India. In any case, both the Indian patterns need a correction and a bigger correction is needed for 1951 than for 1941. But with correction of the pattern, one may have a rough estimate of underenumeration at either of the two Indian censuses.

Table C

MORTALITY INDEX FOR CEYLON, 1900–02, –1952

Age Group	Males 1900–02 $e_0^0=36.99$	Males 1945–47 $e_0^0=47.21$	Males 1952 $e_0^0=57.6$	Females 1900–02 $e_0^0=37.64$	Females 1945–47 $e_0^0=48.66$	Females 1952 $e_0^0=55.5$
0– 4	100	74	54	100	77	55
5– 9	100	51	27	100	46	30
10–19	100	43	17	100	50	25
20–29	100	62	19	100	47	27
30–39	100	57	18	100	58	26
40–49	100	67	23	100	79	24
50–59	100	78	32	100	90	31
60–69	100	91	47	100	90	43
70+	100	100	101	100	100	100

e_0^0 = Longevity

Source: The Demography of Ceylon by N. K. Sarkar (1957).
The figures from the book were adjusted for comparability with Indian indices which were based on probabilities of death.

Analysing the pattern of mortality in India during 1901-1961, one can look at the 1971 census with a 'prepared' eye. The level of improvement in Ceylon of about 1950, is what the experts have assumed for 1971 India in their projections (in 1964). The longevity in 1951 census, if in doubt, was likely to be higher than observed by 1941 standards. In that case the gain observed in 1951-61 is not much and there is much room for improvement in 1961-71, even with the prevalent low levels of living in the country. The increase in medical facilities, the increased coverage in malaria control is expected to bring the backward states in line with the others and the impact of such measures is estimated to be effective in 1961-71 as much as in 1951-61. If not, the health status in the various states is going to be divergent. This would be a blot on the avowed policy by Indian planners of even distribution of the basic and elementary fruits of planning.

One therefore eagerly awaits the 1971 census life-tables. It is hoped. they are not biassed by preconceptions regarding less or more longevity (than that estimated by experts committee) added to Indian life during 1961-71.

Summary

A long term view of the Indian census life-tables during 1901-1961 indicates:

(a) Deteriorating health status of the females vis-a-vis the males.

(b) Mortality for age group 0-4 is less than what is observable elsewhere for the same longevity.

(c) Mortality of age groug 0-4 is also relatively less subject to improvement.

(d) Impact of good or bad times in India was seen on the age group 10-29 years.

(e) The pattern of improvement during 1951-61 shakes the earlier pattern of mortality to conform slightly with what one sees elsewhere in the age group 10-29.

One can either accept the above or revise the life-tables on certain plausible hypotheses.

Infant Mortality in an Urban Setting : The Case of Greater Bombay

Ladislav T. Ruzicka and Tara Kanitkar

The study of infant mortality has a long history and the major determinants are well known [1]. The present article does not aim to discover new factors influencing infant mortality but rather to find out which are the most important ones in the case of a population of large Indian city. It has been repeatedly pointed out that reduction of infant and child mortality is one of the necessary pre-conditions for acceptance of the idea of a small family, particularly in societies which from many reasons continue to attach major importance to male offsprings and their survival to parents' old age. Studies conducted in different parts of the world confirmed that the average number of surviving children is higher among the families who accepted contraception than among the general populations [2]. Practice of birth control is generally lower among women who experienced death of previously born children [3] . On the other hand, close interrelationship between fertility and infant and childhood mortality, well established in the history of countries with presently low mortality levels and in developing countries at present time, indicate that large families with many children are the major obstacle for effective improvement of child's health, prevention of disease and reduction of risk of premature death.

To compute infant mortality rates registration of live births and of deaths before the first birthday is essential. In this respect Indian data are — as is the case in many other developing countries — both incomplete and inaccurate. A few large cities with well organized health services and administration are probably the only exception. Even here, however, disturbing factors are operating: due to inaccuracy in application of the

international definitions of live-birth, stillbirth and infant death omissions and misreportings are probably more frequent than in the developed countries, particularly in cases of deliveries taking place outside hospitals and maternity homes, not attended by medical doctor or trained nurse or midwife. Such deliveries, very frequent in rural India, constitute about 40 per cent of total deliveries in Indian larger towns (Table 1) but are relatively rare in Greater Bombay. During the later 1960's almost 90 per cent of total reported births were hospitalized and it may be therefore expected that the reliability of the records is better here than elsewhere in India.

Table 1

BIRTHS ACCORDING TO PLACE OF DELIVERY AND ASSISTANCE AT DELIVERY (NSS, ROUND XVIII, 1963-1964)

Place of delivery	Assistance at delivery (per 100 deliveries)					
	doctor	nurse	mid-wife trained 'dai'	untrained 'dai'	relatives	none
Towns with 50 thousand inhabitants and more	21.7	20.4	16.9	27.3	11.2	2.5
Towns with less than 50 thousand inhabitants	9.8	9.5	13.0	45.0	20.5	2.2
Rural areas	4.7	1.8	3.7	52.2	33.6	4.0

Annual Records and Reports maintained by the Public Health Department of Greater Bombay give yearly data on registered livebirths and infant deaths, subdividing the latter into 'born in Greater Bombay' and 'born out of Greater Bombay'. Infant mortality rates for the years 1960—1968 both adjusted ones for 'out-born' and unadjusted show a relatively wide fluctuation without any well marked significant tendency towards improvement (Table 2). With respect to age, however, a very significant improvement of mortality rates during later part of infancy (6—11 months) is traceable, whereas neonatal rates (0—27 days) only fluctuated around approximately 45 deaths per 1000 live births throughout the reviewed period. Mortality during the earlier months of the post-neonatal period (4 weeks to 5 months) seems to take a more favourable turn recently.

Table 2

STILLBIRTH RATIOS AND INFANT MORTALITY RATES BY AGE OF INFANTS, GREATER BOMBAY 1960-1968

Year	Stillbirth Ratio	Infant Mortality	0-6 days	0-27 days	4 weeks-5 months	6 months-11 months
	per 1000 live births					
1960	36.7	95.2 (87.2)	29.6	44.3	26.0	24.9
1961	36.7	95.8 (89.4)	29.9	43.7	27.3	24.8
1962	33.6	84.0 (78.4)	28.0	42.6	22.9	18.6
1963	33.8	81.0 (77.2)	28.1	43.9	21.0	16.1
1964	35.6	85.6 (79.8)	29.8	45.6	23.2	16.8
1965	37.8	96.2 (84.0)	30.9	47.2	27.7	21.3
1966	37.2	85.5 (78.6)	31.5	47.7	21.6	16.2
1967	35.6	92.1 (85.1)	30.0	47.0	25.4	19.8
1968	34.7	80.3 (72.7)	29.5	44.8	20.8	14.7

Greater Bombay is administratively subdivided into three areas: City, Suburbs and Extended Suburbs—widely unlike in respect of social, demographic and economic characteristics. The density of population is extremely high in the over crowded City and relatively low in the Extended Suburbs which rather recently started to become both a housing centre and industrial area. During the intercensual period 1951-1961 the average annual rates of growth for City, Suburbs and Extended Suburbs were 1.7, 6.8 and 7.6 respectively [4]. Differentials between the areas in demographic characteristics are seen from Table 3. Sex ratio according to 1961 census was highest in the City (1507 males per 1000 females) and decreased in Suburbs (1358) and Extended Suburbs (1300). Literacy is higher in Bombay than in the Maharashtra State as well as India, and again higher in City than in Suburbs (Table 3-A). Overall work participation rates for males are somewhat higher in the City (63.1) than in the Suburbs (58.6). The industrial composition of workers reveals only slight difference between the City and Suburbs, particularly in the dominance of the tertiary sector in the City (Table 3-B).

Table 3

GREATER BOMBAY: BASIC DEMOGRAPHIC DATA (1968)

Index	Bombay City	Suburbs	Extended Suburbs	Greater Bombay
Area (km^2)	67.78	175.08	194.00	436.86
Population (estimate 1.7.1968) in thousand	3,584	1,340	444	5,368
Density per km^2	43083	6900	2090	10387
Number of live births	81880	55489	19511	156880
Birth Rate (per 1000 population)	22.7	41.4	43.9	29.2
Number of deaths	30697	15616	4126	50439
Death Rate (per 1000 population)	8.6	11.7	9.3	9.4
Number of Infant Deaths	7063	4425	1114	12602
Infant Mortality Rate (per 1000 live births)	86.3	79.7	57.1	80.3
Stillbirths	2873	2053	520	5446
Stillbirth Rate (per 1000 live births)	35.1	37.0	26.7	34.7
Maternal Mortality Rate (per 1000 total births)	0.9	0.8	0.6	0.8

Table 3-A

LITERACY RATES 1961 (IN PER CENT OF TOTAL POPULATION)

State	Males	Females
India	34.4	12.9
Maharashtra	42.0	16.8
Greater Bombay	65.1	48.5

Source: *Times of India Directory*, 1969, pp. 46-48

Table 3-B

PERCENTAGE DISTRIBUTION OF WORKING POPULATION IN BOMBAY CITY AND SUBURBS (1961) BY ECONOMIC SECTORS

Sector	Males		Females	
	City	Suburbs	City	Suburbs
Primary	0.3	4.8	1.6	7.9
Secondary	43.5	47.6	30.7	30.6
Tertiary	56.2	47.6	67.7	61.5

Computed from B-II workers and non-workers classified by sex and broad age groups. *Census of India, 1961,* Vol. X *Maharashtra,* Greater Bombay Census Tables, pp. 176-179.

Housing conditions are somewhat better in the suburbian areas than in the City. Average number of persons per household was, according to 1961 census, 5.6 in City and 4.7 in suburbian areas, average number of persons per room 4.1 and 3.3 respectively. However, it has to be pointed out that 72.9 per cent of households in the City lived in one-room with average number of persons per household 5.4. Conditions were somewhat better in suburbian areas where corresponding rates were 71.3 and 4.3 [5]. According to an expert committee on low-cost housing set up by GOI the shortage of 'pucca' residential buildings in Greater Bombay in 1970 was estimated to be of the order of 568 thousand [6]. According to a survey carried out in 1969 by Bombay Municipal Corporation over 108 thousand huts accommodated about 632 thousand persons, giving an average of 6.3 persons per hut. Only 1333 W. C.s and 432 water taps were available for the inhabitants of the hutment colonies [7]. Probably 15 per cent of total Bombay population consisted of hutmen, slum dwellers or houseless persons. There is no evidence available to show the distribution of this group between the City and suburbian areas [8].

Overcrowding, insanitary housing and environmental conditions, are well known factors contributing to spread of diseases, particularly infections. In this respect differential infant mortality rates (Table 4) seem to reflect the impact of the conditions mentioned

in the previous paragraph. Differences in IMRs between the three areas may not be fully genuine, partly originating from variations in the completeness of registration of births and infant deaths. This seems to us to be documented in the data for suburbs which have a trend almost contrary to IMRs for the City. However, assuming that over time the quality of registration improved rather than deteriorated, mortality differences towards the end of 1960's may reflect the true position of the three areas. Indirect evidence in support of this conclusion can be drawn from the incidence of notifiable infective diseases. In the City and Suburbs the annual incidence rates were almost equal in 1968 (141.5 and 144.0 per 100,000 population respectively). In the Extended Suburbs, however, the incidence rate was only 97.7 per 100,000 population [9]. Tuberculosis and Hepatitis had significantly higher incidence rates in the City and Suburbs as well.

Table 4

STILLBIRTH RATIOS AND INFANT MORTALITY RATES IN GREATER BOMBAY 1960–1968

Year	Stillbirth Ratio			Infant Mortality		
	per 1000 live Births					
	Bombay City	Suburbs	Ext. Suburbs	Bombay City	Suburbs	Ext. Suburbs
1960	41.7	27.2	26.3	109.1	70.2	60.5
1961	41.4	27.8	30.1	113.1	68.0	53.7
1962	37.9	27.1	25.0	95.8	67.3	55.3
1963	36.3	30.1	29.2	87.0	74.6	62.6
1965	39.7	37.6	27.6	106.7	92.9	48.9
1966	38.5	37.3	30.3	89.7	87.3	56.9
1967	35.8	37.1	29.0	98.4	91.5	60.9
1968	35.1	37.0	26.7	86.3	79.7	57.1

Date for 1964 are not available by parts of town.

Infant mortality rates have a distinctive seasonal variation. In Greater Bombay the peak of mortality falls into the monsoon period (Table 5). Contrary to experience of low-infant mortality countries, the early neonatal and neonatal mortality rates (0—6 days and 0—27 days) have a marked seasonal variation as well. From

July through September the mortality rates exceed the average by 10 to 23 per cent with a well marked peak in August. Post-neonatal mortality rates (28—365 days) have a much larger period of increased levels, extending from April through August with a peak in July, excess mortality ranging from 7 to 29 per cent of annual average.

Table 5

SEASONAL MOVEMENT OF INFANT MORTALITY BY AGE OF INFANTS GREATER BOMBAY 1963-1967

Months	Infants deceased at the age of			
	0–6 days	0–27 days	28–365 days	0–365 days
	Seasonal Index (monthly average) = 100.0			
January	106.3	93.6	86.3	89.7
February	97.2	97.1	84.1	87.7
March	91.7	92.9	98.2	87.6
April	94.5	97.9	114.1	99.4
May	102.3	101.0	109.5	99.0
June	96.9	97.5	107.1	98.2
July	110.7	116.0	129.I	117.9
August	123.2	122.6	114.6	110.2
September	117.2	117.0	99.5	117.7
October	98.2	96.6	85.0	103.0
November	87.4	88.8	77.1	90.8
December	74.5	78.9	95.3	98.8

From available data it is not possible to find out the extent which particular diseases contributed to the increased mortality of intants during the monsoon period. It may be, however, presumed that respiratory diseases (pneumonia) and diseases of digestive system (diarrhoea, enteritis, dysentery) are more frequently a cause of death during that period of year [10]. Annual report of the Health Department of the Municipal Corporation of Greater Bombay gives a broad classification of the causes of infant deaths on the basis of which we can at least establish three categories : *infections* (smallpox, measles, diarrhoea, enteritities, dysentery diseases of respiratory system, convulsions, poliomyelitis); *congenital*

malformations (which also include diseases of early infancy)[11]; *others*. With all the limitations of such a broad classification, data for two 'normal' years 1966 and 1968, and for two years of increased infant mortality, 1965 and 1967, can be compared (Table 6-A).

Table 6-A

STRUCTURE OF THE CAUSES OF INFANT DEATHS IN GREATER BOMBAY

Age of Infants	Out of 100 deaths were due to					
	Infections		Congenital Malformations and Diseases of Early Infancy		Others	
	1966-1968	1965-1967	1966-1968	1965-1967	1966-1968	1965-1967
0–6 days	10.0	8.8	69.3	77.1	20.7	14.1
7–27 days	33.5	36.4	48.3	47.5	18.2	16.1
28 days–5 months	62.7	69.2	20.6	17.2	16.7	13.6
6 months–11 months	68.8	73.7	8.8	7.6	22.4	18.7

Neonatal deaths accounted for almost 56 per cent of total infant deaths during the two 'normal' years and for 51 per cent during the two years of increased mortality. Out of 100 early neonatal deaths 9—10 were due to infections and 69—77 to congenital malformations and diseases of early infancy. The structure of causes of deaths changes rapidly with infant's age. In the later part of the neonatal period infections were responsible for approximately one-third of deaths and, in the post neonatal periods, two-third of total deaths were recorded as due to infective diseases. Charecteristically enough, the proportion of deaths caused by infections is high even in the neonatal period of life, a phenomenon which coincides with the housing, sanitary and other environmental conditions described in the preceding paragraphs and at the same time explains the existence of such a well marked seasonal variation in neonatal mortality[12].

Infant mortality rates by leading infective causes of death during 1962-1968 demonstrate the susceptibility of the population to attacks of epidemics. The years 1965-1967 show an outbreak of

smallpox and measles epidemics among infants, but also increased mortality from respiratory diseases (Table 6-B). No data are available to show the interrelationship between malnutrition, undernutrition and infant mortality. However, a study conducted by IIPS in Greater Bombay in 1965 on pattern of feeding of infants [13] gives some important indications about the nutritional situation. According to the findings nearly 50 per cent of the mothers started weaning by the time the child was three months old and 75 per cent by the time the child was six months old. Nearly 83 per cent of the mothers have given as the main reason for weaning that they had insufficient milk. On the other hand nearly 26 per cent of mothers continued to nurse their child beyond one year of age (with supplementary food). Generally an early introduction of supplementary, protein-rich diet in child's nutrition is recommended. The implementation, however, depends on the availability of such food, awareness of the mother and willingness to change the traditional methods of nursing and feeding—in other words on the education of the public and mothers in particular. The Protein Foods Association of India conducts campaigns in urban areas where the protein-rich foods are comparatively easier to obtain in the market. A study conducted by this organisation in Gujarat and Maharashtra on the caloric and protein intake by pre-school children (six months to five years old) estimated the need of 1318 calories and protein requirement as 23.4 grammes per child per day. The actual intake was found to be 709 and 552 calories, protein intake was estimated at 12.8 and 10.7 grammes in Gujarat and Maharashtra respectively. The report also mentioned that the deficiency was not completely wiped out in the families with higher household incomes[14].

Table 6-B

INFANT MORTALITY, GREATER BOMBAY 1962-1968

SELECTED CAUSES OF DEATH

Cause of Death	Death Rates per 100,000 live born in the year						
	1962	1963	1964	1965	1966	1967	1968
Smallpox	7.4	15.9	30.2	160.4	21.0	113.6	5.1
Measles	23.9	15.9	47.5	137.3	26.4	89.4	14.0
Diarrhoea, Enteritis Dysentery	854.9	853.4	883.9	1145.8	1119.0	1069.6	1029.4
Diseases of respiratory system	1913.4	1623.3	1828.2	2907.2	2132.6	2725.9	2001.5

As an indirect indicator of impact of malnutrition on infant mortality the incidence of diarrhoea may be used. Incidence rates of morbidity are not available, however, the death rates in Table 6-B indicate that at least 10 per cent of total infant mortality is due or associated with malnutrition, and, most probably, with elementary food hygiene as well. Many of these deaths are preventable—major obstacle probably being not lack of supplementary food but neglect, ignorance of mothers of the elementary principles of child feeding and of prevention of gross faecal contamination. Incidence of measles and smallpox indicates that even in a city with relatively very good health facilities and maternal and child welfare services easily accessible and entirely free of charge immunization programmes have not reached all exposed to risk.

Greater Bombay statistics of infant deaths give no details which would enable a study of differential mortality with respect to social, economic and cultural characteristics of the families or to age and parity characteristics of the mothers [15]. Data of this type have to be collected by special sample surveys. One of the possible sources of such information may be sought in the surveys primarily oriented to study the fertility levels. History of previous pregnancies is recorded as a routine and frequently the survival of live-born children is followed up with age at death recorded for those who died in the past. If proper attention is given to such surveys and the reference period is restricted to a few years preceding the interview, the extent of 'recall lapse' and other deficiencies may be reduced substantively. The major disadvantage of this particular source of information from the point of view of infant mortality analysis is the limited scope of data restricting the possibility of cross-tabulations with respect to several influencing factors. Vague delimitation of infant's age at death will most probably be a very common feature and therefore interpretations of terms 'neonatal' and 'post-neonatal' cannot be made with absolute accuracy.

A study of fertility in Greater Bombay was conducted during 1966 by the IIPS [16] in which a sample of 7872 currently married women was interviewed. Results of the survey are used in the following paragraphs to study some of the social, economic, cultural and biological determinants of infant mortality. To reduce the impact of possible 'recall lapse' the sample was restricted to 4466

women who reported a termination of pregnancy during the years 1960-1965. During this period 7779 pregnancies were reported (1.74 per woman) as terminated out of which

7166 (= 92.1 per cent) by single live birth,
439 (= 6.1 per cent) by abortion
109 (= 1.4 per cent) by stillbirth

65 by twin birth, out of which in 62 pregnancies both children were born alive and in the remaining three one child was live born and one stillborn.

Abortion rates and stillbirth ratios as established by this study were undoubtedly on the lower side. It partly is due to the methodology of surveys of this type; out of the sample automatically are excluded all women who died at delivery or during the period reviewed. It may be assumed that in case of maternal death probabilities of stillbirth and, for that matter, chances of infant's death as well, are higher than in the general population. There is, however, no possibility to estimate the extent of this omission and its impact on stillbirth ratios and infant mortality rates [17]. Major omissions are undoubtedly due to non-reporting of abortions and possibly also to concealment of stillbirth. The age and parity specific rates (Tables 7 & 8) do not deviate from a generally observed pattern: highest rates are found with youngest mothers and towards the end of the child-bearing period. Somewhat irregular is the trend with respect to the order of pregnancy, though very high orders show a distinctive increase of both abortion rates and stillbirth ratios. No further analysis was conducted because of the strong suspicion of underreporting.

Table 7

GREATER BOMBAY FERTILITY SURVEY 1960-1965: STILLBIRTHS AND ABORTIONS BY AGE OF MOTHER

	Age of mother at termination of pregnancy				
	less than 20	20–24	25–29	30–34	35–39
Abortions per 1000 terminated pregnancies	85.4	53.5	52.3	66.1	69.2
Stillbirth ratio per 1000 total births	19.6	14.9	11.6	15.6	22.7

The number of terminated pregnancies at age 40 and over was only 93 and therefore no rates were calculated.

Table 8

GREATER BOMBAY FERTILITY SURVEY, 1960–1965. ABORTIONS AND STILLBIRTHS BY ORDER OF PREGNANCY

Order of Pregnancy	1	2	3	4	5	6	7
Abortion Rate*	56.7	53.8	56.7	57.4	64.3	71.8	85.6
Stillbirth Ratio*	17.6	13.4	11,7	13.8	13.1	26.5	12.4

*Rates were defined as in Table 7.

Infant mortality rates calculated on the basis of survey data are somewhat different from the usual ones, being birth-cohort mortality rates rather than conventional infant mortality rates. Consequently the calendar year of death may be the year of birth or the following year. Similar definitions apply to neonatal and post-neonatal mortality rates.

Probabilities of infant death are rather consistent with IMRs found for Greater Bombay, considering the size of the sample involved. The annual average for the period was 73.6 infant deaths per 1000 children born alive during 1960—1964 with 49.3 per cent of neonatal deaths (Table 9). With respect to biological determinants the picture is also consistent with well known tendencies. The youngest and oldest mothers experienced highest infant mortality (in both its components, i. e. neonatal and postneonatal). Age and pregnancy order being closely interrelated, the highest infant and neonatal mortality rates were found in the 1st pregnancy, whereas the lowest ones were—in our sample—for the 5th and 6th order pregnancies. For post-neonatal mortality the rates were somewhat higher than average throughout the first to fourth pregnancies. The total number of infant deaths being rather small no much significance is to be attached to the variations of the rates. The calculations were carried out to examine whether the findings agree with known results of other investigations rather than to establish representative rates for Greater Bombay.

The main aim of the analysis of results of ' Greater Bombay Fertility Survey ' in respect of infant mortality was to study the

Table 9

GREATER BOMBAY FERTILITY SURVEY 1960–1965 INFANT MORTALITY RATES (TOTAL AND BY AGE OF INFANTS) BY COHORTS OF BIRTHS

Birth cohort	Infant Mortality	Neonatal Mortality	Postneonatal Mortality
	per 1000 live births		
1960	74.2	36.7	37.5
1961	87.1	44.0	43.1
1962	82.8	40.6	42.2
1963	55.4	28.5	26.9
1964	67.1	29.5	37.6
1965	–	24.7	–

impact of its cultural, socio-economic and environmental determinants in the metropolitan population. Because similar surveys are conducted by IIPS in rural areas of India it may be possible in due time to compare differentials between rural and urban (metropolitan) results. Due to limited number of observations (444 infant deaths) the analysis was carried out by using different sub-groups of population. Total infant mortality rates for the period 1960-4 were used, specifiic by age of mother, as the standard. Age structures of women 'exposed' were known for different strata (by religion, social class, education, place of origin). Theoretical (expected) numbers of infant deaths were then calculated for each sub-group under hypothesis that the social (cultural. etc.) charcteristic does not bear any effect on infant mortality level. By comparing observed and expected numbers of infant deaths a standardized ratio was obtained as

$$SMR = \frac{\text{observed number of infant deaths in sub-group}}{\text{expected number of infant deaths in sub-group}} \cdot 100$$

the value of which exceeds 100 in cases of increased mortality in the particular sub-group of population (and was less than 100 in the opposite case). A simple test of significance was used[18] with 5 per cent level of significance applied throughout the study. Similar procedure was followed for the analysis of neonatal and postneonatal mortality.

Table 10

INFANT MORTALITY RATES BY AGE OF MOTHER, GREATER BOMBAY FERTILITY SURVEY 1960-1964

Age of mother at the termination of pregnancy	Out of 1000 live born children during 1960–64 there died during		
	Infancy	neonatal period (0–27 days)	postneonatal period (28–365 days)
19	127.9	68.0	59.9
20–24	82.5	35.8	46.7
25–29	52.3	27.0	25.3
30–34	46.5	25.6	20.9
35–39	74.3	40.2	34.1
Total	73.6	36.3	37.3
Number of deaths	444	219	225

Table 11

INFANT MORTALITY RATES BY PREGNANCY ORDER (GREATER BOMBAY FERTILITY SURVEY, 1960-1964)

Deaths per 1000 live born children during 1960–1964	Order of Pregnancy						
	1	2	3	4	5	6	7
In infancy	89.4	73.6	70.9	71.4	58.6	64.1	66.4
0–27 days	49.9	36.0	32.0	30.8	24.9	33.3	31.0
28–365 days	39.5	37.6	38.8	40.6	33.7	30.8	35.4

Infant Mortality by Educational Level of Mother:

Educational level was found to be the strongest, most effective single factor determining the level on infant, neonatal and postneonatal mortality (Table 12). Illiterate women had the highest ratets, exceeding the overall infant mortality by 27 per cent (post-neonatal mortality by almost 35 per cent). The lowest rates were found for women with higher than elementary education, and—as expected—with strongest effect in the post-neonatal period (actual rates being only about 30 per cent of the post-neonatal mortality of the total sample).

Table 12

INFANT MORTALITY RATES BY EDUCATIONAL LEVEL OF MOTHER (GREATER BOMBAY FERTILITY SURVEY 1960-1964)

Deaths per 1000 live births (cohort born during 1960–1964)	Illiterate and without formal education	Completed elementary education	Higher than elementary education
In infancy	95.7 (127.5)	51.9 (71.2)	35.7 (53.6)
0–27 days	44.6 (120.1)	27.3 (75.2)	25.5 (78.5)
28–365 days	51.1 (134.9)	24.6 (66.1)	102 (29.7)

Rates underlined are statistically significant at 5 per cent level.

Infant Mortality by Religion of Mothers :

Out of the three groups (the fourth group—'others'—'comprises mostly Parsees and non-specified) the lowest rates were found, as expected, for Christians. The highest rates for Muslim women were close to the accepted level of significance. Contrary to expectation there were no significant differences in the post-neonatal mortality (Table 13). One of the reasons for conspicuous differences of IMRs among different religious groups may be sought in educational differences among them.

Table 13

INFANT MORTALITY RATES AND SMR'S BY RELIGION (GREATER BOMBAY FERTILITY SURVEY, 1960–1964)

Deaths per 1000 live born children during 1960–1964	Hindus	Muslims	Christians	Others
In infancy	75.2 (102.6)	97.4 (120.7)	45.7 (69.6)	59.9 (78.8)
0–27 days	39.8 (97.8)	57.0 (142.8)	24.8 (74.7)	28.9 (81.9)
28-365 days	35.4 (107.2)	40.4 (98.0)	20.9 (63.2)	31.0 (80.6)

Numbers in brackets are SMR's $= \frac{\text{'actual' number of deaths}}{\text{'expected' number of deaths}} = 100$

Social and Economic Status of the Family:

Education is effecting economic and social position of a person in a society, determining his occupation, earning, way and style of living, housing and in both positive and negative way has an impact on his health as well as his family's wellbeing [19]. It may be therefore expected that differentials in infant mortality by social stratification will have similar trends as those found for educational pattern. Economic and social status of the family interviewed were decided by investigators on the basis of several criteria. The orientation was more toward actual standards of living of the family rather than limited to evaluation of income alone. Subdivision into three broad categories was necessitated by the small size of our sample (Table 14).

Table 14

INFANT MORTALITY RATES ACCORDING TO SOCIAL STATUS OF THE FAMILY (GREATER BOMBAY FERTILITY SURVEY 1960–1964)

Deaths per 1000 live born children (cohort born during 1960–1964)	Social Status					
	Low and Lower Middle		Upper Middle		Upper	
In infancy	90.3	*(116.1)*	54.1	*(80.0)*	17.7	*(26.5)*
0–27 days	43.5	*(113.6)*	32.5	*(97.4)*	–	
28–365 days	46.8	*(118.5)*	21.6	*(65.3)*	–	

Even then the highest social class had only 565 women and experienced 10 infant deaths (out of it 3 in neonatal age). The impact of social status was evidently high in infant mortality rates in general and in post-neonatal mortality in particular. Here again the results may be interpreted in terms of knowledge, awareness of child care, and availability of such care. With MCH facilities of a city, access to medical help need not be obstructed by economic hindrances — services being available free of charge. It is most probably lack of knowledge and negligence but also the approachability due to differential social status, which are responsible for the increased IMRs in the lower strata of society than want of health services.

Mother's Place of Origin :

A major part of Bombay's population (64 % in 1961 Census) was born outside the city [20]. It was expected that IMRs will be higher among women who migrated to Bombay from rural areas or from other urban areas in India, because social and educational level of the large part of the immigrants is lower than that of the 'resident' population. The differential IMRs were as anticipated in case of women who immigrated from rural areas: 81.9 per 1000 live births. For the other two groups the differences were negligible (65.3 and 66.0 for those born in Bombay and in urban areas respectively). None of the differences was, however, statistically significant. Similarly no significant differences were found between IMRs for the city and the suburbs.

During the period 1960-1964 the interviewed women gave birth to 110 twins. Out of them 30 died during infancy (IMR = 273 per 1000 live-births); neonatal mortality rate was 191 per 1000 live-born. In 11 out of 55 deliveries of twins both children died during infancy.

The Fertility Survey had not as aim a study of infant mortality. However, even within a limited scope, its results may be used for such a purpose provided the data were collected with care and proper check-up of information obtained. Delimitations of certain events reported may be defective, as it is most probably the case of still-births and live-births of infants who died shortly after birth. Neonatal age may not be accurately discerned from post-neonatal period; even deaths of children somewhat older than one year may be reported as infant deaths. However it may be assumed that such defects are not too many and do not seriously affect the well marked differences among sub-groups of population under study. It is the trend of such differences we are interested in, revealing the 'exposed to risk' sub-groups of population, rather than accurate levels of the mortality rates. Health planning and preventive programmes have to be oriented to 'groups at risk' to be fully effective. Under conditions of scarcity of relevant data any source of possible supplementary information may contribute to this knowledge in spite of the limitations.

NOTES

1 *Foetal, Infant and Early Childhood Mortality.* Vol. II. *Biological, Social and Economic Factors.* United Nations publication, Sales no. 1954. IV, 8.

2 J. R. Rele and Tara Patankar, Differential Fertility by Contraceptors and Non-contraceptors, *IUSSP Conference London 1969*, paper R. 2.2 for further references.

3 J. R. Rele, Fertility Differentials in India. *Milbank Memorial Fund Quarterly*, 41 (1963), 2, pp. 183-193.

Shaffik Hassan, Influence of Child Mortality on Fertility, *Population Association of America, Annual Meeting,* New York 1966.

4 K. C. Zachariah, *Migrants in Greater Bombay,* Asia Publishing House, Bombay 1968, table 1.4.

5 *Census of India 1961.,* Vol. X. *Maharashtra.* Census Tables for Greater Bombay, E-I and E-V.

6 M. Khandekar, *A Report on the Situation of Children and Youth in Greater Bombay,* Tata Institute of Social Sciences, Bombay 1970.

7 Ibid. p. 4-5.

8 Census 1961 data reveal, however, some information on houseless population (pavement dwellers) in Greater Bombay. In Bombay City 1.9 per cent of total population belonged to this category, whereas in Western and Eastern suburbs the percentage was 0.8. Maximum concentration of houseless population in City itself is in the Ward A (southern part of Bombay-Island) with 7.2 pavement dwellers per 100 population. (P. Ramachandran, *Pavement Dwellers in Bombay City,* Tata Institute of Social Sciences, Bombay 1970).

9 Administrative Report of the Executive Health Officer for the Year 1968. *Administrative Report of the Municipal Commissioner for Greater Bombay for the year 1968-69*, Bombay 1969.

10 V. B. Mathankar, V. S. Rao, C. P. Vasudeva, *Differential Mortality in Greater Bombay,* DTRC Bombay, June 1968.

11 The grouping together of congenital malformations and diseases of early infancy is rather unhappy; each group is different in nature. The way data are published renders it impossible to find out incidence for each group separately.

12 Another factor undoubtedly contributing to high neonatal mortality is prematurity, as reflected by birth weights. It has been observed in two studies on birth weights of infants in Greater Bombay that beside the age of mother, parity and duration of pregnancy, social and cultural characteristics, such as religion and occupation have a significant effect on

incidence of infants of 'low birth weight'. See: K. G. Basavarajappa, V. A. Deshpande, K. V. Ramachandran, Effect of Sex, Maternal Age, Birth Order, and Socio-Economic Status on the Birth Weight of Live Born Infants. *Indian Journal of Public Health,* January 1962, pp. 18-27. C. John, P. M. Joseph, *A Study of Birth Weights of Infants Born in a Hospital in Bombay City,* DTRC, Bombay, May 1970.

[13] M. Karkal, *Pattern of Feeding of Infants in Greater Bombay,* IIPS Bombay 1968.

[14] M. Khandekar (1970) *op. cit.* p.38.

[15] An interesting attempt to base analysis of social differentials in infant mortality on deaths only has been made by K. V. Ramachandran and J. Meerding in Infant Mortality according to Social Status in Greater Bombay, *Journal of the Indian Medical Association,* 38 (1962), 9.

[16] J. R. Rele, Tara Patankar (1969) *op. cit.* p. 2.

[17] Maternal mortality in Greater Bombay fluctuated during 1960-65 between 1.9 (1961 and 1962) and 1.0 (1964) per 1000 births. Taking the number of terminated pregnancies reported by the interviewed women in our sample• it may be vaguely assumed that less than 20 women were 'lost' due to maternal mortality.

[18] Standard deviation of SMR equals approximately to

$$\frac{100 \sqrt{\text{observed number of deaths}}}{\text{expected number of deaths}}$$

100 $\pm$ 2 stand. dev. established the 95 per cent confidence limits.
G. M. Howe, *National Atlas of Disease Mortality in the United Kingdom,* The Nelson & Sons, London 1963, p.6.

[19] A simple interrelationship between education and social status, occupation and health, need not be, however, that markedly strong in a traditional society, where neglecting health may be due to other hindrances than economic.

[20] K. C. Zachariah, *op. cit.* p.45.

Analysis of Factors Affecting Infant and Early Childhood Mortality in India

P. S. S. Sundar Rao

Introduction

Infants and children are the most vulnerable group for deaths. Unfortunately, those areas of the world for which the relevant statistical data do not exist or are too defective to be included probably belong to the high or very high childhood mortality [15, 16]. For countries wherein this information exists fairly accurately, a conservative estimate seems to be a loss of nearly 4 per cent of all live births by the fifth year of age. Probably a world-wide weighed average of early childhood deaths would be between 15 and 20 per cent of all live births.

In India, the death rate among children is considered to be very high, contributing to nearly 45 per cent of the total deaths in the country[1, 14]. The causes of this profuse wastage of lives are not satisfactorily described by the existing statistics. Even when the statistics on causes of death are accurrate—and they very seldom are—the best they can tell is the disease or the final medical symptom which preceded death, Thus real explanations which would implicate social and economic factors can only be determined through special studies. In this paper an attempt is made to describe the infant and early childhood mortality status and indicate the probable causes of mortality and future trends.

Definitions

It is important to define initially certain terms and measures commonly employed in studying infant and child mortality. Infant mortality may be defined as the number of infant deaths per thousand live births in one year. Neonatal mortality rate indicates the number

of deaths occurring within 28 days of birth per thousand live births in one year. Postneonatal mortality rate expresses the death rate of infants dying from 28 days to under one year per thousand live births who have survived the neonatal period. Childhood mortality are expressed as age-specific death rates at individual years of age or for age-groups of 1-4 years, 5-9 years and 10-14 years, wherein the number of deaths occurring in any year in these specified age groups are divided by the estimated mid-year populations in the corresponding age groups.

Present status of Infant and Child Mortality

The percentage distribution of deaths registered in India [14] during 1964 by age, sex and area is shown in Table 1.

Table 1

PERCENTAGE DISTRIBUTION OF DEATHS BY AGE, SEX AND AREA: [14] INDIA, 1964

AGE GROUP	ALL AREAS			RURAL			URBAN		
(YEARS)	M	F	T	M	F	T	M	F	T
UNDER 1	18.7	17.7	18.3	18.5	17.0	17.8	19.8	20.2	20.0
1–4	16.4	18.0	17.2	17.2	18.9	18.0	12.8	15.5	14.0
5–9	5.4	5.3	5.4	5.7	5.7	5.7	4.2	4.4	4.3
10–14	3.0	2.8	2.9	3.1	2.9	3.0	2.8	2.7	2.8
15–19	2.9	3.1	3.0	2.9	3.2	3.1	2.6	3.2	2.9
20–29	5.2	6.8	5.9	4.9	6.5	5.7	5.8	8.0	6.8
30–39	6.1	6.6	6.3	5.9	6.6	6.2	6.6	7.2	6.8
40–49	7.7	6.4	7.1	7.4	6.6	7.0	8.4	6.1	7.4
50–59	9.8	7.9	8.9	9.4	8.3	8.9	10.5	6.9	8.8
60 and above	25.4	24.2	24.9	24.9	24.1	24.5	26.5	25.8	26.1

It is observed that in both urban and rural areas as well as among males and females, nearly 44 per cent of all deaths occur among persons under 15 years of age. Nearly 36 per cent of all deaths occur among children under 5 years of age. It is also observed that next to deaths among persons aged 60 years and more, the highest proportion of deaths seem to occur among infants and

those belonging to the age groups 1 to 5 years. The age-specific rates in India are described in Table 2.

Table 2

AGE-SPECIFIC MORTALITY RATES FOR INDIA[16] : 1958-59

Age (Years)	Percentages
All Ages	19.2
- 1	190.3
1 - 4	44.0
5 - 14	5.6
15 - 24	4.5
25 - 34	5.3
35 - 44	5.6
45 - 54	10.5
55 - 64	26.6
65 & over	63.5

It is obvious that the maximum age specific mortality occurs among those under one year of age. The age-specific mortality in early childhood is also high. Subsequently the mortality rates decline attaining a minimum during the age group 15 to 24 years and thereafter increasing gradually.

Infant Deaths:

Infant mortality has been an important index of the social and economic development in a country, largely due to the causative factors involved. As infant mortality rates decline towards the minimum, a larger part is confined to neonatal mortality which comprises of a hard core of causes not amenable to further reductions excepting through progress in medical knowledge. The registered infant mortality rates in India during 1964 varied between 70 and 80 per 1000 live births [7], [8], [14], while the true rates have been estimated at various sample registration and special project areas to vary between 120 and 140 per 1000 live births [7,17]. The infant mortality for selected countries during 1969 is displayed in Table 3.

Table 3

INFANT MORTALITY FOR SELECTED COUNTRIES [17] :1969

Country	Rate
Sweden	12.9
Japan	15.0
Denmark	15.8
Australia	18.3
United Kingdom	18.8
France	20.4
United States	21.2
Canada	22.0
U. S. S. R.	26.5
Philippines	72.0
Guatemala	89.0
Chile	100.0
U A R	117.0
India	139.0
Ghana	156.0
Uganada	160.0
Brazil	170.0

For the developed countries, the figures are all below 30 per thousand live births, while in most developing countries the infant mortality ranges between 100 and 180.

(i) *Age at death of infants :* The proportionate mortality by age in India [14] during 1964 is indicated in Table 4.

Table 4

PROPORTIONATE MORTALITY BY AGE AT DEATH OF INFANT ACCORDING TO SEX IN RURAL AND URBAN AREAS [14] (PERCENTAGES)

Age	Rural		Urban	
	Male	Female	Male	Female
0 - 6 Days	23.9	22.3	32.5	28.4
7 - 28 Days	20.5	19.4	18.9	17.9
29 Days - 5 Months	25.6	26.9	25.4	27.2
6 Months - 11 Months	30.0	31.4	23.2	26.5
Under one year	100.0	100.0	100.0	100.0

It is observed that nearly 45 per cent of infant deaths occur during first four weeks life. This is true for both males and females and in both urban and rural areas. This pattern is quite unlike the status observed for countries with low infant mortality [8,16] as shown in Table 5.

Table 5

INFANT MORTALITY BY AGE IN SELECTED COUNTRIES[16]
1964—'65

Country	Under One Year	Age of Infant				Rate of Neonatal : to Post-Neonatal Death Rate
		Neonatal		Postneonatal		
		0–6 Days	7–27 Days	28 Days-5 Months	6–11 Months	
Sweden	13.4	9.6	1.0	1.8	1.0	3.8 : 1
Australia	18.5	11.7	1.6	3.4	1.8	2.6 : 1
Switzerland	18.9	12.9	1.4	3.0	1.6	3.1 : 1
England & Wales	19.1	11.3	1.7	4.5	1.6	2.1 : 1
France	19.4	9.3	2.6	5.0	2.5	1.6 : 1
Japan	20.4	8.6	3.9	5.3	2.6	1.6 : 1
Canada	23.6	14.7	1.7	5.5	1.7	2.3 : 1
U. S. A.	24.8	16.1	1.8	5.1	1.8	2.6 : 1
Austria	28.3	17.8	2.2	5.1	3.2	2.4 : 1
Mexico	60.7	14.3	18.6	22.9	14.9	1 : 1.7
Gambia	72.0	28.4	9.7	15.9	18.0	1.1 : 1
Colombia	82.4	20.9	12.5	–49	.0–	1 : 1.5
Guatemala	87.9	18.9	15.9	29.8	23.3	1 : 1.5

While most countries with low infant mortality have a ratio between the neonatal and postneonatal mortality rates as 2 : 1 or 3 : 1, the situation in India is the reverse showing a ratio of nearly 2 : 3. This phenomena is peculiar to countries where infant mortality rates still continue to be high (Fig. I)

Table 7

CAUSES OF INFANT DEATH BY AGE IN MADRAS CITY DURING 1964[14]

Cause of Death	Age				
	0–6 Days	7–28 Days	29 Days–5 Months	6–11 Months	0–11 Months
All Causes	1955	1192	2204	2452	7803
Cholera	...	...	2	3	5
Smallpox	...	11	26	59	96
Measles	...	...	...	4	4
Diphtheria	...	1	1	4	6
Enteric Fever	...	...	...	2	2
Malaria	...	...	...	1	—
Other Fever	24	55	46	60	185
Dysentery	4	20	202	249	475
Diarrhoea	6	58	302	392	758
Infantile Debility and Malnutrition including Premature Birth	1068	380	161	21	1630
Diseases of Respiratory System	147	242	920	854	2163
Convulsions	6	9	27	13	55
Illdefined	700	416	517	790	2428

(c) *Interval between births*: The shorter the time interval between births, the greater the risk to the survival of the infant.

(d) *Family size* : The risk of death increases with the size of the family, which often varies inversely with the degree of social and economic advancement.

(e) *Cultural practice* : Certain primitive customs and habits greatly influence the infant mortality. Branding of the skin, application of cowdung to the cut end of the umbilical cord, frequent purgation, faulty feeding and weaning practices are some of the cultural factors associated with high infant mortality in India.

(f) *Midwifery and Health manpower* : Shortage of trained personnel like midwives, dais, and health visitors is another cause of high infant mortality in India. In India, local barber women are still

responsible for a large number of deliveries. These are usually illiterates with meagre knowledge of rules of hygiene.

(g) *Environmental sanitation*: Lack of a safe water supply, poor housing conditions, bad drainage, overcrowding, and insect breeding all increase the risk of infant mortality.

The major causes for neonatal mortality are prematurity and congenital malformations. In 30 to 50 per cent of cases, the cause of prematurity is unknown. A number of social conditions have been shown to be associated with low birth weight. Women who work late in pregnancy, for example tend to have babies of lower birth weight than those who have no occupation during pregnancy or who stop work during the early weeks. Rates in areas of cities where housing is poor are higher than those in good residential areas. Women with low levels of nutrition in pregnancy have higher rates than those where nutritional levels are high. All these factors may be correlates rather than causes, and the mechanism by which social factors are translated into biological events is not clear.

The problem of congenital malformations is a complex one comprising many aspects of medical science[13]. The specific causes of many of the congenital malformation may be mutations, chromosomal abnormalities or adverse intra-uterine environment as a result of infections in the mother or use of teratogenic agents. The role of consanguineous marriages in this aspect is also to be fully evaluated.

Early Childhood deaths:

Excessive numbers of deaths beyond the first year are not characteristic of most industrially developed areas. But for technically underdeveloped countries, deaths within the age group of 1-4 years contribute heavily to the crude death rates, often equalling or exceeding first year deaths.

The magnitude of the deaths occurring during 1-4 years of age in relation to infant deaths is shown in Table 8.

(i) *By age*: The mortality rates or ratios by single years of age for the pre-school years are not available excepting through

special studies and surveys carried out in various parts of the country. Some idea of the death rates in Punjab by individual years are shown in Table 9.

Table 8

PER CENT RATIO OF DEATHS 1-4 YEARS TO DEATHS UNDER ONE YEAR IN SELECTED COUNTRIES: 1965[16]

Country	Ratio Per cent
Guatemala	93.3
India	89.5
Gambia	64.4
Colombia	56.2
Mexico	51.7
Japan	26.2
Australia	22.3
U.S.A.	21.1
Switzerland	19.8
France	19.7
Canada	18.1
Sweden	17.2
Austria	17.0
England and Wales	16.3

Table 9

PERCENTAGE OF DEATHS DURING EARLY CHILDHOOD, BY YEAR OF AGE IN RURAL PUNJAB, INDIA, 1957-59[6]

Age (Years)	Per cent
1	70.0
2	19.2
3	7.5
4	3.3
Total (1–4)	100

Second year deaths exceed those of any other in the pre-school years. Even in advanced countries and under the best conditions, more than one-thirds of preschool deaths are in that year. If the neonatal period is eliminated, death rates of the second year commonly rival those of infant mortality in magnitude and in specific attributes.

(ii) *By cause*: The main causes of death in the early childhood are those characteristic of the postneonatal period of infancy, where infectious disease and malnutrition are the chief considerations. In the second year. however, malnutrition assumes more importance and its interaction with acute infections, enhances the clinical severity of infectious processes and mortality[6]. Multiple causal factors however, operate as usual in the Indian setting, some primarily biologic, others social or cultural. After the second year, death, rates decline progressively to lower levels, although with varying promptness, under the influence of specific environmental features.

An idea of the role of environmental factors can be obtained from a comparison of the causes of death in various age-groups of children[14] as shown in Table 10.

Table 10

PERCENTAGE DISTRIBUTION OF DEATHS BY SELECTED CAUSES OF DEATH[14] IN EACH AGE-GROUP OF CHILDREN, INDIA, 1964

Disease Group*	Disease Code[18]	Age [Years]				
		0	1–4	5–9	10–14	Total
I	010–019	1.6	10.7	11.5	22.5	6.3
II	000–009, 022–136	5.2	15.5	30.7	20.8	11.5
III	140–239	0.1	0.3	0.9	2.5	0.4
IV	241–299	3.7	8.3	3.7	5.0	5.0
V	300–458	6.1	15.6	17.9	15.0	10.5
VI	460–519	6.4	12.6	5.0	2.5	7.7
VII	520–577	11.6	23.5	7.8	5.0	14.1
VIII	580–629, 680–734	0.4	1.4	2.8	3.3	1.1
IX	741–779	59.2	1.2	0.4	0.8	33.8
X	780–796	4.4	7.3	7.8	4.1	5.6
XI	N800–N999	1.3	3.6	11.5	18.3	4.0
Total		100	100	100	100	100

* I Tuberculosis

II Other Infective and Parasitic Diseases

III Neoplasms

IV Endocrine, Metabolic Diseases, Nutritional Deficiences, Diseases of Blood and Blood Forming Organs

V Diseases of Nervous System, Sense Organs and Circulatory System

VI Diseases of Respiratory System

VII Diseases of Digestive System

VIII Diseases of Genito Urinary, Skin, Subcutaneous and connective Tissue, Musculoskeletal System

IX Congenital Anomalies, Causes of Perinatal Morbidity and Mortality

X Illdefined

XI Injuries, Accidents.

Even as broad cause-groups, the impact of environmental factors seem clear.

Future Trends

The infant mortality rate while still high, has shown a consistently downward trend over the past few decades as displayed in Table 11, for India and in Fig. II for Madras city[2].

Table 11

INFANT MORTALITY RATES IN INDIA[12]

Period	Infant Mortality Rate
1901 – '06	215
1906 – '11	228
1911 – '16	204
1916 – '21	219
1921 – '26	174
1926 – '31	178
1931 – '36	174
1936 – '41	161
1941 – '46	161
1946 – '51	134
1951 – '60 (Estimated)	139
1971 (Expected)	96.3

INFANT MORTALITY RATES IN MADRAS CITY
1925 – 1964

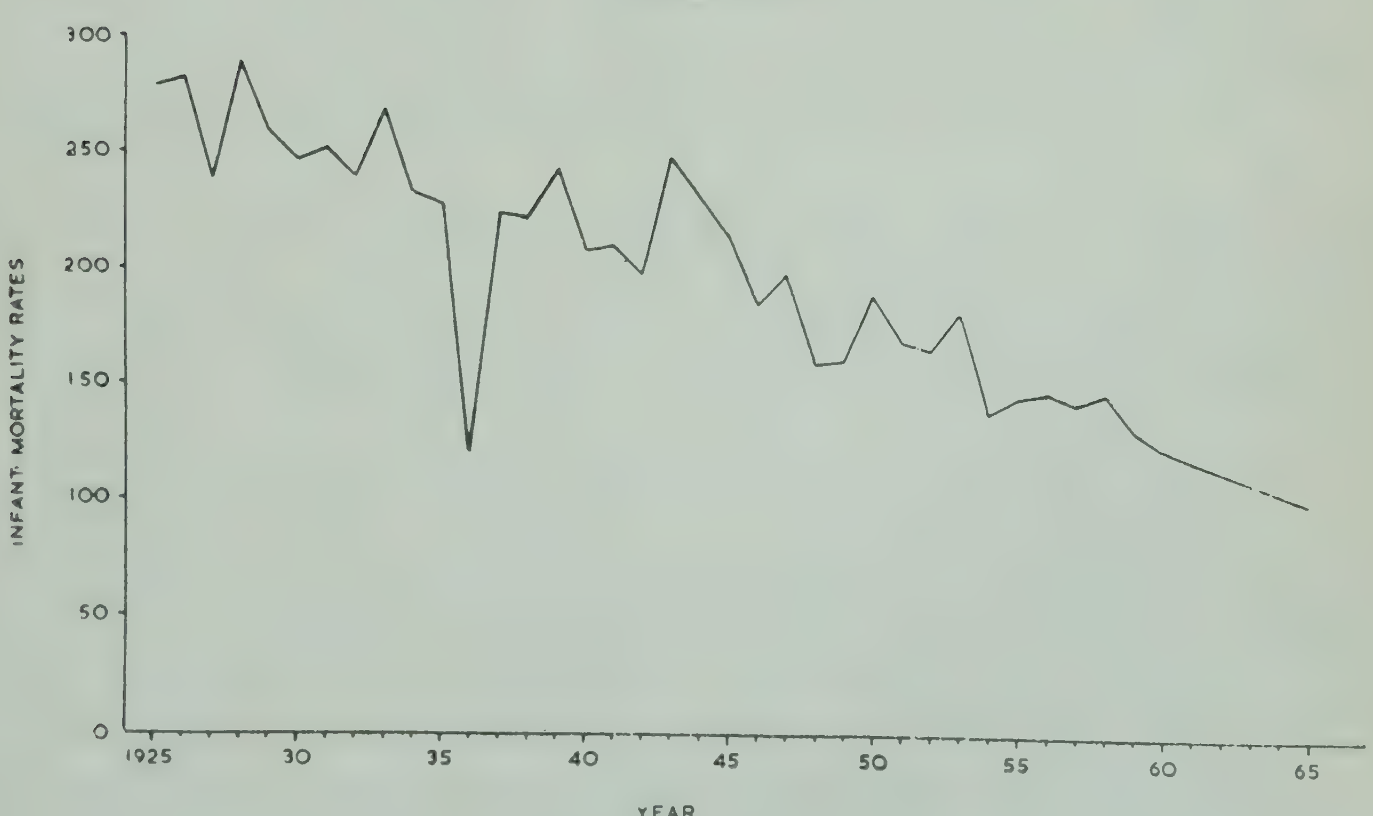

Figure 2

The experience in other countries wherein reductions in infant mortality have occurred may be useful in predicting the trends in India.

The per cent annual rates of decline in selected countries[10] are shown in Table 12.

Table 12

PER CENT ANNUAL RATE OF DECLINE IN INFANT MORTALITY RATES FOR THE STATED TIME PERIOD FOR THE COUNTRIES OF LOW MORTALITY [10]

Country	Period I	Per cent Annual Rate of Decline	Period II	Per cent Annual Rate of Decline
England and Wales	1943 - '54	6.1	1955 - '62	1.9
Norway	1945 - '55	5.9	1956 - '62	3.1
Sweden	1936 - '55	5.0	1956 - '62	2.0
Netherlands	1949 - '56	4.7	1957 - '62	2.6
Switzerland	1945 - '56	4.3	1957 - '62	1.7
United States	1933 - '49	4.3	1950 - '62	1.1
New Zeland	1943 - '53	3.3	1954 - '61	0.5
Australia	1944 - '54	3.2	1955 - '62	1.4

After a period of exceedingly favourable infant mortality experience, there began to appear in the early 1950's indications of deceleration in the rate of decline. This change appeared first in the trend for the United States and later in other countries.

In Figure III is shown the trends in infant mortality by age in India during 1960-'64. (see facing page) Deaths during the postneonatal period have obviously shown the maximum decline and there is practically little change in the first week deaths.

The experience of countries of low mortality has significance for the developing countries which are now at the stage where many

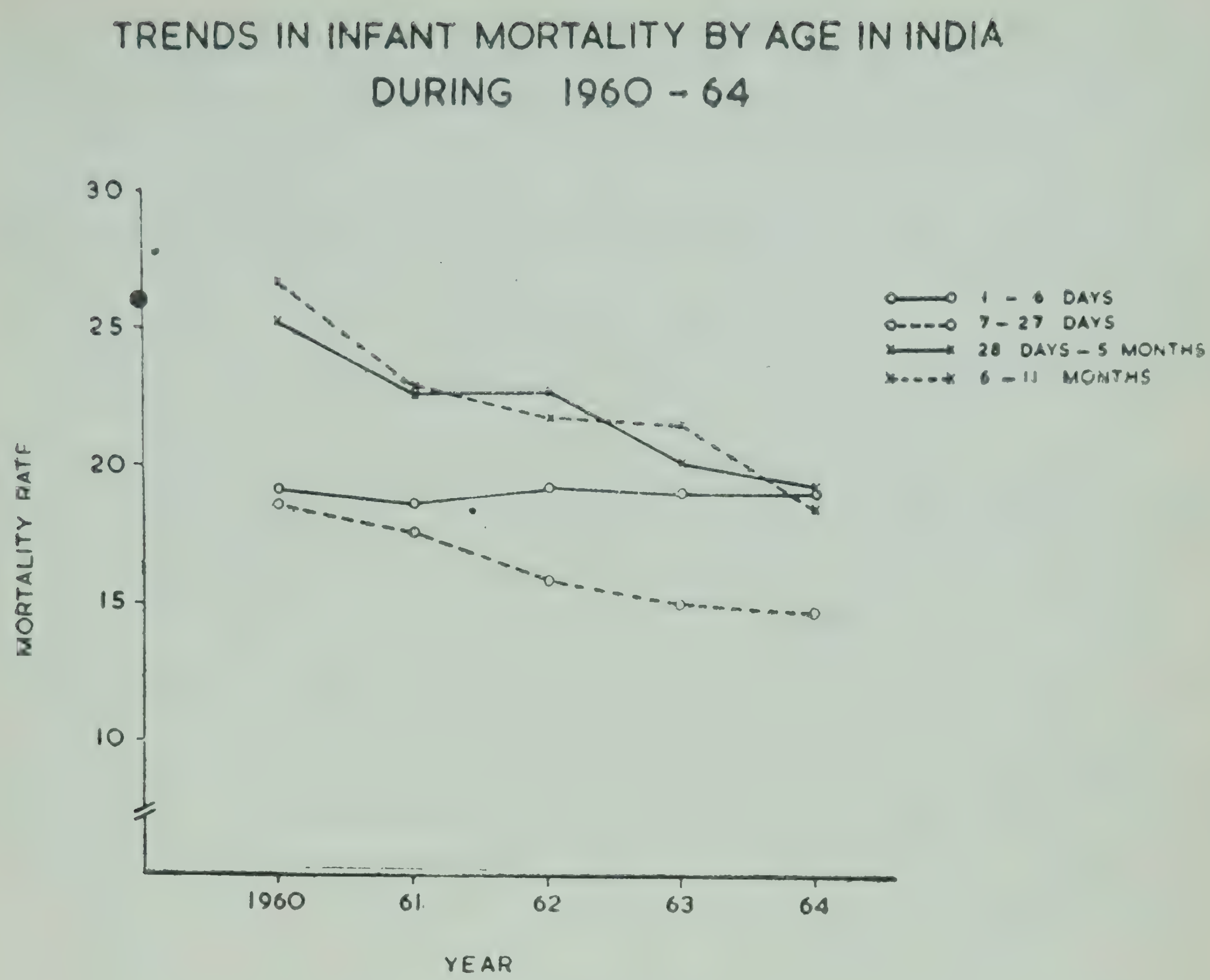

Figure 3

of the developed countries were some forty or fifty years ago. The availability of knowledge and of the technical means for preventing infant deaths from diseases of infectious origin makes it possible to reduce the infant mortality rate substantially in a relatively short period of time in the developing countries.

Conclusions

While the present infant mortality rate is still high in comparison to what has been achieved in the advanced countries, considerable reductions were made in the past two decades.

The decline in infant mortality has been attributed to (a) improvements in the standard of living (b) better control of communicable diseases (c) advances in chemotherapy, antibiotics and insecticides (d) better nutrition (e) better obstetric and other health services. However, a significant portion of the infant mortality still occurs in the postneonatal and early childhood period, the neonatal

mortality, is also unduly large. Substantial progress is therefore to be expected in future. Further action programmes to reduce infant mortality must be based on reliable classification of causes of death.

Because infant mortality is an important determinant of the average length of life, the lowering of infant mortality can add significantly to the average life expectancy in areas attempting to cope with the the problem of rapidly increasing population.

Deaths in early childhood have long held secondary interest to infant mortality and to the problems of the school child. They warrant greater emphasis in politics which guide activities in maternal and child health. Death rates at these ages, more than at any other age, respond promptly to improved social conditions; in Great Britain their decline anticipated that of infant mortality by 40 years. They react sensitively to war years, economic depressions, and other times of social stress. The diseases mainly responsible, infections and malnutrition, are largely preventable. The promise of public health accomplishment is good.

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Current Research on Morbidity and Mortality in the Indian Council for Medical Research

A. D. Taskar and Shantha Madhavan

With the advancement of medical science in recent years and with the use of new drugs and modern methods of treatment, the emphasis has shifted from mortality to morbidity in medical research. As Logan (1965) had put it, mortality is being replaced by morbidity as an index of sickness and health. With the progress of time, the pattern of diseases has been changing so rapidly that the attention of medical scientists has to be focussed on these newer problems, probing for the etiology of these diseases and assessing their magnitude. Thus the need for measuring morbidity in medical research has become imperative. In order to supplement the clinical profile and to know more about the underlying factors, detailed information is needed on the epidemiology of morbidity.

In India, the Indian Council of Medical Research has been the premier organisation for sponsoring and conducting research on various aspects of medical and public health problems in the country. The research activities of the Council are carried out at three levels. Firstly, at the seven permanent institutes, secondly at a number of semi-permanent research units and thirdly under a large number of ad-hoc enquiries of a limited duration, which receive financial support from the Council. The Council plays not only an effective role in promoting biomedical research in the country but also helps to increase the research potential in the country by providing training and research facilities to scientists.

The Council had in the earlier days, directed its interest on understanding the epidemiology of mainly communicable diseases as malaria, filariasis, cholera, plague, kala-azar, leprosy, hookworm

infections and problems of diet and nutrition. With the appearance of newer problems, the Council has been adopting its research policies to meet the needs of such new situations. As the importance of other non-infectious diseases such as cancer, cardiovascular diseases, metabolic disorders, mental health etc., is gaining more and more recognition, additional facilities for research in these fields have been created. Recently, the Council has launched a number of collaborative studies, in order to know the variations in the distributions of the diseases and regional differences, which call for comparative studies of morbidity, as a basis for research on etiology.

Cancer:

The epidemiological aspect of cancer research has attracted world wide interest in recent years and the Council is planning to take active part in the epidemiological programmes of the international Agency for Research on Cancer, Lyon, France. At the national level, the Council has recently initiated studies in the field of oncology, which would help in the understanding of the etiology of the disease as well as its prevention.

Cancers of the oral cavity, uterine cervix and the breast together constitue over 60 per cent of all malignant tumours in our country (I.C.M.R. Bulletin Oct '71). The Council has initiated collaborative epidemiological, clinical and cytological studies on these three tumours at various centres in the country.

Oral Cancer :

Oral cancer in India shows considerable variation in its frequency in different parts of the country. A collaborative study on epidemiology of oral cancer has been set up at Ahmedabad, Guntur, Kanpur, Trivandrum and Vishakhapatnam. By adopting uniform methodology in all these centres, collection of useful data on the epidemiology and possible prevention of oral cancer may be achieved.

In an epidemiological survey to study the prevalence of oral and oropharyngeal cancer in textile mill workers of Ahmedabad, 57634 workers from 77 mills and other organisations were examined,

and 33 cancer cases were detected giving an annual incidence rate of 28.6 per 100,000 persons. Tobacco chewing is the most common practice amongst the workers here.

A similar study was carried out in Mainpuri District, Uttar Pradesh. The incidence rate of oral cancer was 21.4 per 100,000 population. Buccal mucosa was the commonest site, involved. Strong association was observed between the prevalence of oral cancer and the chewing of 'Mainpuri' and Pattiwala types of tobacco.

Cervical Cancer:

Cancer of the uterine cervix is the commonest cancer affecting Indian women, and its frequency varies from region to region in the country. A collaborative study on epidemiological clinical and cytological aspects of this cancer has been sponsored by the Council at Agra, New Delhi and Madras. At each centre, cases and normal subjects will be taken from hospital, drawn from a specific areas of one million population. Uniform proforma will be used by all the centres to collect data.

A study of genital carcinoma in women was carried out at the S. N. Medical College, Agra, and 39587 females were screened over a period of 3 years. It revealed genital carcinoma and dysplasia in 711 and 941 cases respectively. Of the 711 cases of genital carcinoma, 693 were cases of cervical carcinoma, giving a rate of one out of every 57 women in a population of 39,587 examined. Cervical cancer occurred more in women who were multiparous or had long reproductive period.

Another epidemiological study was conducted on the prevalence of cancer of uterine cervix with special reference to the role of certain environmental factors in its etiology in the urban and rural areas of the district of Agra. Out of the cervical smears of 26,533 women aged 20 years and above examined, the three year prevalence rate of carcinoma and dysplasia of the cervix was observed to be 0.63 and 6.28 per cent respectively. On analysing the data according to religion, age at marriage, number of pregnancies and socio-economic status, it was observed that Hindu women had a greater risk of cervical cancer than Muslim women.

Cancer of the Breast:

It is postulated that factors which predispose to uterine cancer have a protective action on breast cancer. An epidemiological study of breast cancer vis-a-vis cervical cancer is being carried out in two hospitals in New Delhi city.

The Council has undertaken an epidemiological study on breast cancer in an urban population of Delhi. The aim of this study is to find out the prevalence of breast cancer and to evaluate the significance of various etiological factors in the occurance of breast cancer particularly in relation to lactation.

Cardiovascular Diseases & Hypertension:

Cardiovascular research conducted under the auspices of the Indian Council of Medical Research includes fundamental, laboratory and applied research as well as clinical and epidemiological studies. While on the one hand the research activities of the Council relate to the foremost killers—rheumatic heart disease and ischaemic heart disease, the Council has also been actively studying medical problems of interest to our defence services such as high altitude hypoxia and cold stress.

Coronary Heart Disease:

Epidemiological studies of coronary heart disease were carried out at New Delhi, Agra and Bombay, in urban population over 30 years of age. In New Delhi, the prevalence of ischaemic heart disease was reported to be 5.5 per cent in the high income group and below 1 per cent in the low income group. The study at Agra gave a prevalence rate of 5.3 per cent, showing a significant relationship between the disease and sex, age, socio-economic status and serum cholestrol level. In a similar study at Bombay among a population of low socio-economic group, the prevalence rate was found to be 2.9 per cent, and the important influencing factors were noted as overweight, inadequate exercise, higher serum cholestrol level and greater prevalence of hypertension and diabetes.

Rheumatic Heart Disease:

Rheumatic heart disease is another important cause of morbidity in the young. The Council has recently initiated a collaborative

study on the epidemiology of rheumatic heart disease with participating centres as Agra, Alleppey, Bombay, Hyderabad and New Delhi. The aim of the study is to determine the prevalence of rheumatic heart disease among school children who form the most vulnerable group for this disease and to study in detail the natural history and pattern of the disease in different parts of the country. It has been proposed to examine 40,000 school children between 5-16 years of age at each centre. The cases of rheumatic heart disease picked up from these would be followed up for detailed study.

In Chandigarh, a study on rheumatic fever and rheumatic heart disease was carried out in the urban population and in the neighbouring rural areas. Through a house-to-house survey 33,361 individuals were examined on a random sample basis. The prevalence of chronic Rheumatic Heart Disease and Rheumatic fever was found to be 1.23 per 1000 males and 2.07 per 1000 females. 60 per cent of the cases with rheumatic heart disease gave a history suggestive of rheumatic fever in the past. This study revealed that this disease was highly prevalent among females, which demands measures for early detection, prevention and treatment, in young women particularly.

In New Delhi, a survey of 2544 school children between the age of 5-15 years showed a prevalence rate of rheumatic heart disease of 6.0 per cent.

Diabetes Mellitus

In the field of clinical endocrinology, the collaborative study instituted last year by the council on diabetes mellitus in India is in progress at six centres namely Ahmedabad, Calcutta, Cuttack, New Delhi, Poona and Trivandrum. The study aims at finding out the prevalence of diabetes mellitus in both the urban and rural populations of different parts of the country, and also to work out the clinical and biochemical profile of untreated diabetic persons on a country-wide basis. For the prevalence study each centre is to examine 7000 individuals above 15 years of age. The data on clinical profile and biochemical profile are to be obtained from 200 and 50 untreated diabetics respectively, in addition to 50 normal subjects as controls for biochemical profile.

Preliminary data from Ahmedabad had shown that the prevalence of diabetes mellitus in the rural areas near Ahmedabad is 1.21 per cent. Diabetes was found to be more common after the age of 30 years with a male; female ratio of 1.4: 1.

Thyroid Disease :

A pilot survey was completed on hypothyroid patients in school children of Chandigarh. Compulsory use of iodised salt was introduced in Chandigarh and neighbouring rural areas in 1963, as a result of the low iodine content of natural water in these regions. The present survey revealed that goitre was still endemic in a small percentage (16.4 per cent) of school children of Chandigarh even after four years of iodine prophylaxis.

Epilepsy :

A collaborative epidemiological study of epilepsy in India is being carried out in five centres in India, namely, Bangalore, Bombay, Calcutta, Madras and New Delhi. The objectives of the study are: (a) to identify in a particular geographic area, a hospital referred population of patients with convulsive disorders; (b) to classify clinically such patients of convulsive disorders; (c) to determine, in so far as possible, the etiology of the convulsive disorders (d) to institute therapy and evaluate effects on the individual patients and (e) to collect data on social and religious factors for study of the effects of socio-cultural and economic factors on etiology of epilepsy and prediction of effectiveness of management. From the data collected so far, some of the observations made were that head injury was found to be the commonest etiological factor, birth trauma being the next common one and also major epilepsy accounted for the highest per cent of cases.

Growth and nutritional Status of Children :

A survey on physical growth and nutritional status of children of 5 - 10 years carried out in New Delhi, showed vitamin A deficiency in 4.7 per cent and diminished vision in 28.5 per cent. An adverse socio-economic status had more effect on weight than height. Further follow-up was being carried out to compare the morbidity

pattern of children in the longitudinal study with that of those in the semi-longitudinal one, belonging to the age group 5-10 years.

Studies on skeletal maturation, i. e. appearance of ossification centres were conducted on 1007 children. The skeletal maturation of girls was found to be faster than that of boys. It was also observed that pattern of skeletal maturation of Indian children was similar to that of American children except for a slight delay in the ossification of trapezoid and ulna and marked delay for capitallum.

Cross-sectional studies on infant growth norms are being carried out in four centres namely Agra, Madras, Poona and Varanasi. These studies are on the same lines as the country wide survey on growth and physical development of Indian children 1 to 20 years conducted by the Council during the year 1956 to 1961, the preliminary data of which were published in 1968 and the final detailed report is now under print.

Nutrition and Infection :

A prospective clinical field study on young rural children to study the interaction of nutrition and infection was carried out at the Rural Health Research Centre at Narangwal, Ludhiana. The objectives of the study were 1) to determine the effect of nutritional status on the incidence of infection in children 0-3 years, as well as the effect of infection episodes on nutritional status and 2) to study the effect of medical care and nutritional supplements on both nutritional status and the incidence of infection.

These interactions were to be studied in eleven Punjab villages divided into four groups which were to receive a) nutritional supplements alone (b) curative and preventive health care mainly concentrating on infectious disease control through inmunization and early treatment; (c) a combination of nutritional supplements with curative and preventive health care; and (d) a control group receiving only minimal symptomatic care.

Preliminary findings of the work carried out so far suggested that i) morbidity was reduced in the groups of villages receiving combined care; (ii) a significant increase had occurred in the rate of increment of both height and weight in the cohort receiving services

(iii) haemoglobin levels were higher in the nutrition supplemented cohort as compared to the child care and controls cohort; (iv) age of weaning had increased significantly in the two year period of observation.

Tuberculosis:

Tuberculosis prevention trial is being conducted under the Council. The aims and objectives of the study are: 1) to assess the value of BCG in the prevention of tuberculosis under the conditions existing in India (ii) to decide the feasibility of chemoprophylaxis trial in India. During a period of 2 years and 8 months, 2,96,794 persons were vaccinated with BCG or placebo. 2,36,199 persons were examined by X-ray and 53,467 persons were referred for sputum examinations and 2,206 culture prositive cases of pulmonary tuberculosis were found. The follow-up is being maintained every six months. The study is still in progress.

In another study trends in tuberculosis were studied in an urban community in Delhi. A series of four longitudinal surveys over a period of 8 years has yielded some interesting data relating to the epidemiology of tuberculosis in the study area. The prevalence of tuberculosis has shown a definite fall during the last two years of the study period, in the community followed up.

In a tuberculosis morbidity study carried out at the Institute of Child Health and Hospital for children, Madras, a total of 4,608 children were tested with 3 antigens (PPD-5, PPD-6 and Fraction 403) simultaneously. Follow-up studies revealed a high prevalence of infection; by the age of 12 years, 40 per cent of children were already infected.

Poliomyelitis:

The enterovirus unit of the Council at Bombay routinely collects epidemiological data on paralytic poliomyelitis in Greater Bombay. Age distribution of cases showed that the disease affected mainly children in the age group 7 months to 2 years.

The unit had extended its activity to the rural area of Sirur Taluk (Poona District), conducting virological survey. 31.5% of the

child population. between the age 6 months to 6 years showed entero-virus infection. Polio type 2 and 3, echo types 7 and 19 were the predominant strains isolated so far. The antibody survey showed that about 90% of the population did not have normal antibodies against all the three polioviruses.

Cholera:

The Council has been deeply interested in all aspects of cholera research and has been supporting it during the last few decades. As part of the epidemiological studies, cholera carrier studies have been carried out, since cholera carriers have been found to play an important role in the epidemiology of cholera. It was observed that cholera carriers existed in endemic communities even in the absence of overt disease. The prevalence of carriers in a community in the absence of a case may be about 1.5 per cent as revealed by single sampling. However, on repeated daily sampling for ten days or more, contacts of cholera patients showed a higher prevalence (24.2 per cent) and carriers were found to excrete vibrios intermittently for an average period of 6–15 days. Carriers were also found capable of transmitting infection to their contacts.

Tetracycline was tried for mass chemoprophylaxis and though it reduced the duration of carrier states to an average of five days, it was not considered suitable for use in an endemic area because of the possibility of reinfection.

Infectious Hepatitis :

Studies on epidemiology of infectious hepatitis carried out by the National Institute of Communicable Disease, Delhi, indicated that all ages were equally affected so far as hospitalised cases were concerned but from field studies, 89% of the cases were below 20 years of age.

Epidemiological investigations revealed that student nurses, attending on infectious hepatitis patients were exposed to higher risk of infection.

Venereal Diseases :

A serological survey to study the prevalence of syphilis and gonorrhoea was carried out in Trivandrum, Kerala. 3313 persons

attending the hospital were examined and an overall sero-positivity rate of 2.14 per cent was observed. In a total of 1610 cases of cardiovascular syphilis admitted over a period of one year, 15 were found to be due to syphilis.

A similar study carried out in Simla in the patients attending hospital, showed a positivity rate of STS as 13.8 per cent out of 2269 persons examined. The maximum rate of sero-positivity has been found to be in the age-group of 41-60 years of age. The rates revealed that the disease is on the decline in Simla Hills.

Leprosy :

The Council has sponsored many studies on the epidemiology and treatment of leprosy. Large scale clinical and field trials on prophylactic treatment of leprosy with DDS are in progress in Wardha, and Chingleput, Madras. The study at Wardha showed the incidence rates in the prophylaxis group as 0.24 (1967-68), 0.54 (1968-69), 0.82 (1969-70) and 0.22 (1970-71), and in the control group the corresponding figures as 1.87 (1968-69), 1.28 (1969-70) and 0.98 (1970-71). While chemotherapy has proved itself to be useful for treating patients, its value as a prophylatic still needs to be elucidated further.

Dental Survey:

An epidemiological survey on dental health was carried out in Punjab, Kerala and Madras under the sponsorship of the Council. In each region, both urban and rural population of five selected districts was studied for various oral and dental disorders with reference to age, sex, chewing habits, oral hygiene methods etc. A large proportion of the surveyed population was found to be affected by periodontal disease, with its inception in early childhood and increasing in severity with advance in age. The prevalence was more in females than in males of both urban and rural population.

An intensive survey of endemic fluorosis in the hyperendemic rural area of Punjab revealed a very high incidence of dental (44-81%) and skeletal (28-81%) fluorosis although no strict correlation could be established between these two manifestations of fluorosis. The men were observed to have more of crippling and neurological

fluorosis than women. The main factors determining fluoride toxicity were fluoride concentrations in drinking water and the period of exposure to the hazard. The minimum threshold of fluoride toxicity for dental conditions was found to be less than 1 ppm for Indian conditions, the optimum level being 0.5 to 0.6 ppm. Mottling of enamel was prevalent even in those areas where the water fluoride concentration was below 0.6 ppm.

Silicosis :

A study among stone cutters in Rohtak has thrown light on the fact that there is a gradually increasing prevalence of silicosis among stone cutters and there was an increase in the grade of the disease with the duration of employment. The risk of pulmonary tuberculosis was found to be increased two-fold in cases with radiological evidence of silicosis than those with such an evidence.

Byssinosis :

In a modern textile mill in Bombay, 286 workers were screened to study the prevalence of byssinosis. Radiological examination, pulmonary function tests, blood examination for eosinophilia, besides the routine investigations were carrid out on each worker. Byssinosis was suspected in 40 out of the 286 workers studied, the diagnosis being definite in 23 of them. In 17 workers, there was a suspicion of byssinosis which needed further study for confirmation. In a control group of 173 workers studied, there was no evidence of byssinosis. The investigation is still in progress.

Mortality Studies :

Perinatal mortality was investigated in 15,838 births at Safdarjung Hospital, New Delhi. The incidence was found to be 80.9 per 1000 live births. Maternal haemorrhage, anaemia and toxaemia accounted for 60.5 per cent of perinatal deaths, and abnormal mode of delivery in 26.07 per cent. The rate was inversely proportional to the birth weight upto 3.5 kg. Autopsy done on 60.2 per cent of perinatal deaths showed anoxia and congenital malformations as the two main causes. Pneumonia and pulmonary haemorrhage was the common cause of early neonatal deaths, and not hyaline membrane disease which was common in other countries. The study is still in progress.

In a follow-up study of pregnant women in a rural area with no facilities for antenatal care, near Hyderabad city, a total of 117 pregnant women were studied to determine the outcome of pregnancy, which was as presented in table 1.

Table 1

NO. OF CASES OF COMPLICATIONS IN PREGNANCY, HYDERABAD SURVEY

	No. of subjects	
Pregnant women followed-up	117	
Resumption of menstruation within 14 weeks of pregnancy ? Abortion	7	
Miscarriage during later half of pregnancy	2	
Cases of Angular Stomatitis	69	
Albuminia	5	
Oedema + Albuminia	5	
Eclampsia	3	
Maternal mortality	2	(Eclampsia and Antepartum traemilyse)
Stillbirths	9	
Livebirths	101	
Twins	2	Sets
Congenital deformities in offspring	2	(1 Meningococle, 1 hare lip and cleft palate)

From the above table, it could be seen that 84.6 per cent were live births, while abortions and miscarriages accounted for 7.7 per cent and still births formed the remaining 7.7 per cent. Out of the 117 pregnancies, 2 maternal deaths occurred.

In another follow up study of 855 pregnant women from the maternal and child health centres in Hyderabad city, the outcome of pregnancy was determined and it was observed that 91.5 per cent had fullterm normal deliveries, while abortions, miscarriages and stillbirths accounted for 5 per cent of total pregnancies. 1.5 per cent of the total were premature deliveries and about 2 per cent were caesarian deliveries.

A longitudinal study of morbidity and mortality pattern of 1964 children under the age of five years in an urban community of Delhi was undertaken between 1962 and 1967. Analyses of morbidity and mortality data by sex, socio-economic status, environmental sanitary background of the families, literacy level of the mother and the order of birth of the child were done. The findings are summarized in Table 2. From this table the influence of various factors on the incidence of morbidity and mortality of children is evident. There is a negative association between morbidity and mortality rates and socioeconomic status, type of house and education of mother but a positive association with order of birth.

Concluding Observations

Having reviewed the various research activities of the council, it will be in order to take stock of its contribution to the overall goal of improving the health of the nation and how the future activities of the Council can help in furthering this goal. The Council has indeed achieved its major objective, namely, promotion of medical and allied research in the country on aspects of causation, mode of spread, and prevention of disease. Its research activities utilize the tools of a wide spectrum of disciplines and cover fields of communicable diseases, nutrition, maternal and child health, reproductive biology, epidemiology and fertility control. These studies include both applied and clinical research and basic and fundamental research which can contribute towards the prevention as well as control of diseases and bring about further reductions in morbidity and mortality.

There are three areas of research which call for greater attention in the coming years:

1. Evaluative Studies,

2. General Studies for Public Health Purposes,

3. Studies on Special Aspects of Morbidity and Mortality.

In the first group one may include pilot studies to determine the likely effects of a public health measure as well as studies to evaluate whether the implementation of a programme achieved the desired objective. Examples of such studies are those carried out to determine the effect of an antimalarial drive on the crude death rate or the

Table 2

INCIDENCE OF MORBIDITY AND MORTALITY OF CHILDREN UNDER FIVE YEARS OF AGE BY DIFFERENT CLASSIFICATIONS

Classification		Number of Children	MORBIDITY Months of follow-up	Number of episodes of sickness	No. of episodes of sickness per year of follow-up	MORTALITY No. of deaths	Percentage of deaths
Sex	Male	1,018	15,789	13,902	10.6	79	7.8
	Female	946	14,517	12,615	10.4	96	10.1
	Total	1,964	30,306	26,517	10.5	175	8.9
Socio-economic status	IV	840	13,665	12,286	10.8	114	13.6
	III	695	10,079	8,886	10.6	48	6.9
	II	335	5,217	4,463	10.3	11	3.3
	I	94	1,345	882	7.9	2	2.1
	Total	1,964	30,306	26,517	10.5	175	8.9
Type of house	IV	1,299	20,010	18,186	10.9	139	10.7
	III	420	6,663	5,947	10.7	29	6.9
	II	112	1,781	1,190	8.0	5	4.5
	I	133	1,852	1,194	7.7	2	1.5
	Total	1,964	30,306	26,517	10.5	175	8.9
Education of mothers	Illiterate	1,345	20,476	18,665	10.9	142	10.5
	Literate	619	9,830	7,852	9.6	33	5.3
	Total	1,964	30,306	26,517	10.5	175	8.9
The level of literacy of mothers	Primary	320	5,329	4,582	10.3	20	6.2
	Middle	119	1,889	1,448	9.2	6	5.0
	Higher secondary	99	1,358	960	8.5	4	4.0
	University standard	81	1,254	862	8.2	3	3.7
	Total	619	9,830	7,852	9.6	33	5.3
Order of birth	First	273	3,826	2,781	8.7	17	6.2
	Second	282	4,062	3,532	10.4	22	7.8
	Third	322	3,944	3,496	10.6	29	9.0
	Fourth	332	4,592	4,129	10.8	31	9.3
	Fifth and over	755	13,883	12,579	10.9	76	10.1
	Total	1,964	30,306	26,517	10.5	175	8.9

introduction of triple vaccine on the infant death rate. In the developing countries, the improvement of health has been due to specific public health and medical measures as well as general improvements in levels of living. An evaluation of the relative contribution of these factors will enable the effective allocation of resources for different kinds of programmes.

In the second group of studies one may include the studies which aim at determining the levels of morbidity and mortality in different geographic areas or sections of the population, and the contribution of medical and general factors to the variations in the rates of morbidity and mortality. For example, a national health survey, or surveys to determine the prevalence of particular ailments will fall within this group. The third group of studies will be of a special nature and will concentrate on the etiology, mode of transmission and conditions facilitating prevention or early cure of specific ailments. Such studies may involve screening and follow-up and cannot be on large scale and is useful in studies of cancer, heart and lung diseases and occupational ailments.

The broad classification of areas for future research is not meant to be exhaustive or mutually exclusive. The research work on any one of the above areas is bound to be complementary to each other. It is hoped that during the Fifth Plan period the Council will be able to devote more attention to these research activities.

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Public Health Aspects of Mortality Trends and Levels*

Alwyn Smith

Sources and Quality of Mortality Statistics

There are few societies in which individual death is not regarded as of public consequence. The event has usually a social, legal and religious significance which results in public notice being formally taken of it. In societies where formalized observances are usually or invariably associated with documentary records, a basis will clearly exist for at least an elementary statistical treatment of population mortality, and in at least a part of all member States of the World Health Organization some statistical mortality data are available.

Informative analysis of such data will usually depend on comparisons of the load of mortality experienced by identifiably distinct populations categorizable by their spatial, temporal or other disposition. The minimum requirements for meaningful comparison will involve complete or representative enumeration of deaths in a population whose number can be established with reasonable accuracy. Useful mortality statistics therefore depend on complete or representative recording of occurrences of death among a population of known size.

More informative mortality statistics will permit the calculation of death rates for definable time intervals and sub-populations, the rates being specific for age, sex, and attributed cause, and, in ideal circumstances, for season, locality and other factors.

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The sources of mortality statistics must therefore include sources of information on the circumstances of deaths as well as sources of sufficiently accurate information on the population in which the deaths take place. The most valuable source of mortality data has been the statutory registration with medical certification of cause of death and census-based estimates of population size and the population distribution by place, age, sex and time. Advanced systems of mortality statistics will additionally employ data on mortality before and during birth as well as on the population of births. Data of this kind exist for a part, if not the whole, of most countries, although the extent of national coverage and the duration of the historical sequence of data available vary very widely.

Wherever statutory death registration is established, it should not be too difficult to record for each death, the date and place of occurrence and the age (possibly in broad groups), and the sex of the deceased person. Some kind of opinion on the casual circumstances is usually recordable although certification of the cause by a physician will only be usual in societies where death is usually accompanied by medical attendance.

It is not always necessary to statutory death registration that the responsibility for registration be borne by the kin of the deceased. Death registration may be quite effective even in relatively poorly developed areas provided that the responsibility for registration can be vested in some individual able and willing to exercise it.

In the absence of direct data on deaths as they occur, some countries have recourse to mortality estimation by indirect methods. These may include sample mortality surveys, and subtraction of age distribution derived from successive censuses.

However, it is not always easy to obtain reliable data on the population age distribution and few countries have regular censuses at intervals of less than ten years. The lack of good population data may reduce the value of the data derived from death registration, particularly where migration complicates the estimation of population in the intercensual intervals.

There is little doubt that mortality data are best derived from routine registration of all deaths and are best analysed in terms of population data based on regular censuses. The fundamental need is to be able to compute annual mortality rates specific for sex and age for each distinct area of public health interest. If age cannot be obtained in accurate numerical terms, it may nevertheless be valuable to have the data in broad age groups in which it is possible to distinguish the ranges 0, 1–4, 5–14, 15–44, and 45 and over.

Provided that equivalent population data are also available, it is useful to be able to distribute deaths by marital status, urban or rural residence, social or economic status, place of death (hospital, etc.), and—for countries where migration is important—place of birth. Where it is possible to obtain useful opinions on the cause of death, this is also an important item of information. More detailed information which is worth collecting where it is possible includes the duration of the terminal illness, the basis for the opinion as to cause of death, the number of dependants left by the deceased, details of birth registration of the deceased, the occupation of the deceased and, in some countries, his ethnic group. For deaths occurring before, during or shortly after birth, it is useful to record birth weight and duration of gestation. A complete list of desirable items may be found on page 114 of the United Nations publication *Handbook of Vital Statistics Methods.*

The sources of the basic information will usually include the registrar of deaths, the registrant (usually next of kin of deceased) and the medical attendant or institution able to supply medical data. The kind of information it is useful to attempt to record will be determined by these basic sources.

Public Health Applications of Mortality Statistics

Mortality statistics are a particular example of morbidity statistics. They relate to morbidity of extreme severity and have a number of important advantages over other kinds of morbidity data. First, death is unambiguous and, at least in statistical applications, has no need of definition. Second, the event is easily referred to a defined place and time. Third, each person experiences death only once and there can be no confusion between "event-oriented" and

"person-oriented" statistics. Fourth, the occurrence of death is unlikely to be often concealed or overlooked; mortality statistics are quite commonly complete. Fifth, there can be no argument about the importance of an episode of illness defined as terminating in death.

There are, of course, a number of disadvantages. Mortality statistics do not relate to all episodes of illness nor even to all episodes of any particular kind of illness since few diseases have a fatality rate of 100 per cent. They are clearly unsuitable as a means of estimating the population load in respect of illnesses which are commonly chronic, recurrent or rarely fatal. There are frequently intractable problems in the attribution of death to particular disease causes; in the developed countries a relatively small proportion of deaths can be confidently attributed to a single underlying cause. Nevertheless, the most effective remedy for each of these disadvantages is augmentation of mortality data by morbidity data rather than replacement.

Mortality statistics, because of their unambiguity, completeness and general availability, remain the most sensitive index of variations in the level of health of populations and provide a clear basis for hypotheses concerning the determinants of variation, which may be tested by appropriate means. Their informativeness depends first upon their completeness and second on the analysis made of them.

The advantages of mortality statistics over other forms of morbidity statistics is, however, mainly that they exist on a much more widespread scale throughout the countries of the world. They are used to define the principal problems confronting health services, to monitor the efficacy of health programmes, to warn of impending changes in the patterns of morbidity and as a basis for predicting the longer-term problems of public health.

There are respects in which each of these functions can be enhanced in effectiveness by increasing elaboration of the available related data, and there are increasingly public health problems of importance which mortality data do not illuminate at all (e.g. developmental disorders in children, narcotic addiction, sickness

absence in industry). It is, however, still unusual for any important examination of public health issues to dispense wholly with mortality data.

Analysis of General Mortality

Most countries of the world have enjoyed a period of sharply falling crude death rates for at least a part of the last 150 years. In general, the countries who were first to show a falling death rate experienced a slower rate of fall and these countries have experienced a check in the rate of decline (or in some cases a slight rise) in more recent years. Countries whose rates began to fall later, experienced a sharper fall. The rate of fall has usually been very different at different ages—being generally maximal in the age-range 5-34 years and beginning earlier at those ages. Mortality at later ages has fallen less in most countries and in some it has risen in recent years.

The effect of these changes is different in the short term from that in the long term and is influenced by the concurrent levels and trends in levels of the birth rate. Initially, the main effect must be to increase population size and to shift the age distribution in the direction of the younger ages for so long as the birth rate remains high. If the birth rate then begins to fall—as happend in most of the countries whose mortality decline began early—population growth is slowed and the age distribution begins to favour the older ages.

Although a decline in mortality has been an almost universal experience, the background to the decline has been somewhat different in different countries. For example, in England and Wales, where mortality began to fall quite early, the contribution of specific health and medical measures must have been negligible for the first 100 years, and the early decline must be attributed mainly to improvements in the standard of living and especially in the stability of the available nutrition. In many of the countries with recent sharp declines in mortality, the causes must be much more substantially related to specific health and medical care and the declines have been achieved in spite of relatively small improvements in nutritional availability. In more recent years, in the developed countries, the decline in mortality has spread into the very early years of life and has been maintained well in childhood and early

adult life, although the decline has not been maintained in later life. It is difficult to predict the likely effect of a continued spread of medical care within the developing countries in the probable absence of a substantial increase in available food supplies and with the possible continuation of high birth rates.

For these and other reasons, comparisons between countries at one time or between periods in the history of a single country may be misleading if based on the crude death rate. Mortality is far more dependent upon age than upon any other identifiable attribute of a population and mortality indices that are independent of the age structure of the population are desirable. Of the many such indices available, the expectation of life at birth is commonly used although its name is rather misleading. Unfortunately, calculation of this (or of any other age-independent index) calls for data which are not often available in developing countries.

Although historical trends in mortality can be examined for only a few countries in respect of age-independent indices—or indeed at all—current mortality data can be compared quite extensively on an international basis. The comparison may be even more extensive if crude death rates are accepted since these are almost universally available. The observable range is large, particularly when it is remembered that crude death rates will vary less than age-independent indices since the countries with more favourable mortality experience have usually an appreciably older population. Variation is quite clearly related to levels of social and economic development and very much less to differences of climate and geography.

It is not necessary to have access to data on causes of death to offer some interpretation of such historical and international data as are available. Before the present century, there were no medical measures capable of influencing the fatality of diseases to more than a trivial extent. Until the last twenty years of the last century, no specific preventive measures has been applied to any large population on a scale likely to have had any effect. The decline in mortality observed during the nineteenth century must therefore be attributed mainly to general improvements in the environments which may have affected both the general disposition to contract diseases and the general capacity to survive them. From what we know of social

changes during this period, we are forced to conclude that the most important elements in these changes were the improved nutritional standard of the population and perhaps an improved standard of child care associated with rising aspirations and falling birth rates.

Since the decline in mortality began earliest in children and young adults and since there are good grounds for accepting that it was largely due to a decline in mortality from infectious diseases, of which tuberculosis was the most important, we may safely conclude that environmental changes were incomparably more important than any changes in the disease-resisting capabilities of the human species. Because infectious disease has been an important source of mortality in young people since human beings first began to live in social aggregates, the species is likely to have developed a fairly substantial capacity to resist it before the present decline began.

In the present century, our capacity to modify resistance to infection has been further enhanced by prophylactic and therapeutic innovations which have been added to measures for the interruption of the transmission of infective agents. These developments will have reduced the selection pressure in favour of resistance to infection and it is likely that the inherited capacity of our species to resist infection has diminished rather than increased. In passing, it may be noted that an effect of these developments will be to increase the proportion, in the older population, of individuals with a lower resistance to infection. This may be a contributory factor in the recently observed retardation of the mortality decline in the older age groups in some developed countries.

If the genetic resistance of the human species to infection was acquired to any extent by selection in favour of resistance during the reproductive or pre-reproductive phase of life, and at the expense of a liability to degenerative and neoplastic diseases in later life, the failure of environmental changes to modify experience of these latter diseases becomes more readily explicable. This may also help to explain our relative lack of success in devising prophylactic or therapeutic procedures for the latter diseases compared with the infectious diseases in respect of which genetically determined mechanisms were available for harnessing or augmenting.

The mortality experience of the human species during the past 150 years may be summarized as a substantial and widespread decline, due predominantly to technical innovations which began by effecting general improvements in living standards in a few countries and later led to specific health-promoting procedures which have been quite widely applied. The effect of these general and specific changes has been very largely confined to aspects of mortality where genetic characteristics of the human species have been favourable to their operation. In many areas, the decline has proceeded so far that a continuation cannot be expected without the introduction of some new factor or factors capable of modifying our resistance to a quite different range of disease experience. There is also the danger that the presently established trend may be self-limiting if the consequent population expansion is not countered either by falling birth rates, increased food production or both together.

Special Studies in Mortality

Infant mortality:

The study of infant mortality has been considered especially important for several quite different reasons. First its contribution to the expectation of life is great both because it is early and because it is high. Second, the causes of infant mortality are largely distinct from those that operate at other ages. Third, infant mortality remained intractable long after mortality in the remainder of childhood had declined substantially. Fourth, infant mortality has generally been conceded to reflect quite closely the prevalent standard of living.

In the developed countries, infant mortality has fallen fairly steadily during the present century. The postneonatal component (after the first 28 days) has generally fallen much more quickly than the neonatal (the first 28 days). The relative level of these components provides an index of environmental standards on an international scale and as between identifiable sub-groups of a population of births. The causes operating in the postneonatal period stem largely from the postnatal environment while those of the neonatal period reflect the hazards of the prenatal and intranatal periods and the occurrence of early developmental accidents.

The differences between neonatal and postneonatal infant mortality are demonstrated by the very much greater association of the latter with social class although both exhibit a well marked association. Historical data generally demonstrate that the association with social class has been relatively unaltered by the general reduction in mortality and class differences remain substantial in most countries.

Associations are usually also demonstrable with maternal age and with birth order. The sharp association with birth order is almost entirely confined to infant mortality from infectious diseases but the association is particularly marked in poorer areas where an inverse association with maternal age is also marked. In Birmingham in 1947 the overall infant mortality was 35 per 1,000 but that for the fourth or later children to mothers under 25 was 98. The overall rate from infections was 14 per 1,000 but for fourth or later born children to young mothers in the poorest wards of the city it was over 80. Infant mortality from infection, particularly of the respiratory and gastro-intestinal tracts, is still a major component of human mortality in the socio-economically less favoured populations.

Infant mortality has recently shown some retardation of its decline, particularly in the developed countries. The extent to which this is attributable to a residuum of currently untreatable conditions is arguable, but in countries where the infant mortality rate is below 15 per 1,000, it is certainly the case that the causes are predominantly prenatally or intranatally determined.

Perinatal mortality:

No international definition of perinatal mortality exists but it is usual to define the perinatal mortality rate as the number of deaths in the first seven days of life plus the number of late foetal deaths (stillbirths) divided by the total number of births (live and still). In many studies of perinatal mortality a somewhat wider definition has been employed and late foetal deaths plus all neonatal deaths have been included.

Two distinct reasons exist for combining prenatal and postnatal deaths in this way. First, the legal definitions, and administrative

procedures of the various countries differ in such a way as to make either category difficult to compare on its own. Second, the causes of death at this period of life are substantially the same whether death takes place before, during or shortly after birth.

Perinatal mortality accounts for a large part of all mortality particularly in the developed countries. In most of the countries of Europe, perinatal deaths outnumber deaths in the next thirty years of life and in some countries the next forty years. The certified causes include congenital malformations, birth injuries, asphyxia and neonatal infections but in most countries the circumstances most associated with perinatal mortality are the social class of the parents and the maturity of the infant at birth. Social class variations are such that in Scotland, if all births enjoyed the perinatal mortality of births to parents in social class I (the most favoured), more than twice as many lives would be saved as are lost in road accidents and more years of human life than are lost from all forms of cancer. Although social class seems less important in some studies its general importance seems undeniable.

The association of mortality with maturity at birth has prompted much research into the determinants of foetal growth rates and the duration of gestation. It is clear that much immaturity arises from normal variation in these two attributes but there is evidence of a discrete group of adventitious factors which affect them abnormally.

Perinatal mortality results from hazards of the prenatal and intranatal environment and to some extent from accidents of gametogenesis or embryogenesis. Transmitted hereditary defect is unlikely to be a common cause since there must be intense selection against the relevant genotypes. The relevant environment may be considered under three distinct heads: abnormalities of the maternal reproductive tract, hostile influences capable of crossing the placental barrier and abnormalities of the birth process. None is easy to investigate, and aside from obvious influences, such as errors of implantation, maternally ingested drugs or viruses, and major obstetric catastrophes, we are largely ignorant of their detailed nature. However, the association of nearly all causes of perinatal mortality with parental social circumstances, and the association of most causes with one or more of such factors as maternal age, season

of birth, place of delivery, duration of antenatal care, suggests very strongly that the immediate environment of the mother is of great importance in determining the perinatal survival of her child.

Early foetal mortality:

At least 15 per cent of all human individuals die before they have reached the twenty-eight week of prenatal life. Although some of this mortality is deliberately induced, either with or without legal or moral sanction, a considerable mortality at this period must be attributed to "natural causes". It has nevertheless attracted very little attention. Most studies of aborted foetuses have been directed more towards understanding normal and abnormal development than towards preventing foetal or embryonic death. In fact, spontaneous abortion is often thought of as a mechanism for the disposal of the results of gross developmental accidents.

The principal difficulties in the way of population studies of early foetal mortality are those of access to complete or representative data. Few countries have systems of registration and even where such systems exist, default is probably common. In addition, very early abortions may be associated with little disturbance of menstrual rhythm and many therefore escape detection. Nevertheless, the study of spontaneous foetal death at ages earlier than twenty-eight weeks would be valuable now that obstetric technique has begun to permit survival of such early foetuses in appreciable numbers. It seems likely that before very long, these techniques will have advanced to the point where early evacuation of the uterus need not be associated with foetal death and therapeutic termination of pregnancy will be compatible with foetal survival. Aside from the moral issues that this will raise, there will be a number of important questions related to early disease experience and fatality. The possibility of extra-uterine foetal survival is likely to make termination of pregnancy more acceptable and therefore more common.

Maternal mortality:

Maternal mortality remains substantial in many parts of the world despite its having fallen to trivial levels in the most favoured countries. It is important because it necessarily represents a loss of young adults and because of the social effects on the bereaved families

that are left. It is also important because the experience of developed countries demonstrates that it is substantially preventable.

Maternal mortality rates (deaths from deliveries or complications of pregnancy, childbirth and the puerperium divided by the number of live births) vary very widely throughout the world but have generally been declining. In 1960, rates varid from 30 per 100,000 in Denmark to 303 in Ceylon, while figures for the same countries in 1950-52 were 72 and 571. In recent years, the decline has generally been most marked in the countries with the highest rates—presumably a reflection of the greater proportion that are currently preventable in the countries with the higher rates. Countries with rates around 30 per 100,000 usually find that a large proportion of the deaths are attributable to sudden and unheralded conditions such as amniotic embolism.

In the world as a whole, the largest group of causes is the Toxaemias (A116) which account for nearly one-fifth of all maternal deaths. Although the cause of toxaemia remains essentially obscure, its effects can be very substantially modified if diagnosis is made early and prompt action is taken. Maternal mortality from toxaemia therefore reflects poor levels of prenatal care.

Haemorrhage (A117) accounts for nearly as many deaths as toxaemia. The extent to which mortality from this group of causes is preventable is demonstrated by the very wide variations between different countries, there being a more than tenfold difference between the highest and the lowest rates.

Sepsis (A115) also shows a wide variation in mortality levels and accounts for about 10 per cent of all maternal mortality. This group of causes also reflects the quality of available obstetric care.

The residual group of other and undifferentiated causes (A120) accounts for more than a third of maternal mortality in the world as a whole. This group of causes show a clear association with advancing maternal age and a tenfold variation between the countries with the best and the worst rates.

In the world as a whole, the problem posed by maternal mortality is principally one of applying existing obstetric knowledge

rather than of developing new skills. It is a question mainly of trained human resources and of how they can be provided and deployed.

Maternal age and birth order:

The mortality of mothers and of their offspring is related in a complex way to maternal age and parity of birth order. Reference has already been made to the sharp association of infant mortality from infection with birth order, and in the poorer socio-economic circumstances, with younger maternal age. Stillbirth rates are generally associated with advancing maternal age at any birth order and in a U-shaped way with birth order at any maternal age. Maternal mortality rises with advancing age.

The association with maternal age and birth order of the individual causes of mortality as well as some commonly non-fatal conditions demonstrates that these attributes are indices related to a wide variety of environmental influences. Generally, prenatally determined mortality rises with advancing maternal age, is higher in first and in fourth or subsequent pregnancies. Postnatally determined mortality is generally lower at later ages and at earlier birth orders. The patterns are complicated by the correlation of maternal age and birth order, of both, with social class, and of maternal age with multiple pregnancy, Paternal age seems relatively insignificant as an independent influence.

In relation to maternal age the various adverse influences largely balance each other and that there is no basis for selection of an optimal age within the normal age range. Indeed the optimal maternal age to reproduction seems to be the age that is most convenient and acceptable to the mother.

On the other hand, the marked association of infant mortality and the lesser association of perinatal mortality with birth order, especially with orders higher than the fourth, indicates the desirability of providing special attention for multiparous mothers and their children. In addition the combination of late birth order and relatively young maternal age is associated with a high infant mortality especially when this occurs in adverse social and economic circumstances.

Several important causes of reproductive wastage are sharply associated with maternal age or birth order. Down's syndrome, which has a high fatality, approximately doubles in incidence for each five year increase in maternal age. No other abnormality is known to be so sharply related to maternal age but Klinefelter's syndrome—another trisomic condition—shows a clear association and it may be that some other forms of aneuploidy are similarly associated.

Anencephaly is an important cause of stillbirth whose incidence is related independently to maternal age and birth order. Its association with these variables as well as with season and its secular fluctuations strongly suggest a causal factor in the maternal environment.

Haemolytic disease of the newborn, due to incompatibility of maternal and foetal red cell antigens, shows a pronounced relationship to birth order arising from the usual need of an earlier pregnancy to evoke maternal antibodies.

An important aspect of maternal age and birth order is that they are easily recorded and help to identify "at risk" pregnancies in relation to maternal, foetal and infant mortality. They are also indicators of the presence of hazardous influences in either the prenatal or postnatal environment.

Occupational and socio-economic variations:

Study of the risks associated with particular occupations probably necessitates longitudinal studies of morbidity occurrence rather than analysis of national mortality data. Occupational mobility may invalidate unqualified inferences drawn from data on the occupation at the time of death. Nevertheless, if due regard is paid to this and to other difficulties, occupational mortality data may yield valuable hypotheses about the effect of occupations and their associated social context on the development of disease. For example, there are many occupations into which it is unusual to enter shortly before death and many in which mobility is limited. Similarly, it is unusual to be able to transfer to an occupation of a higher status or salary in consequence of a disability. Disability is much more likely to be involved with occpational mobility in the opposite sense.

Occupational mortality analysis required that age and occupation be recorded in respect of all deaths and that the numbers and age distribution of the related occupational populations be available. Such latter data are usually only available at around the time of censuses of the population. A difficulty is that occupational data from censuses derive mostly from the occupied persons whereas the related data on deceased persons derive necessarily from others. The lack of identity of source for the two sets of data may distort comparisons if too specific an occupational analysis is made.

The considerable differences in the age distribution of the personnel in different occupations necessitates the use of age independent indices in comparing the mortality of large numbers of occupations. The Standardised Mortality Ratio is to be preferred from among the various available indices since it is equivalent to a maximum likelihood estimator. It also has the advantage that it expresses mortality in each occupation as a percentage of overall mortality when age has been allowed for and is thus immediately meaningful in many practical contexts.

Study of occupational mortality data has been quite fruitful. So far as individual occupational hazards are concerned, the occurrence of skin tumours from lubricating oils and bladder tumours in various chemical industries are among many examples of important discoveries that have been based on occupational mortality data.

The mortality hazards associated with an occupation may stem from many aspects of the particular employment. They may arise from the work itself, from the regions in which it is pursued, or from the socio-economic concomitants. In some cases, occupational drift may account for an occupation that recruits substantially from those disabled by chronic illness showing a high mortality from chronically disabling disease (e. g. piano-tuners, car park and lift attendants).

In the United Kingdom. a classification of occupations has been used throughout most of the present century which permits the distinction of five "social classes" based on occupation. These are ranked in socio-economic terms so that class I represents the

professional and managerial class, class III the skilled workers and class V, unskilled workers, while classes II and IV are intermediate classes. There is a difficulty in constructing such classifications because knowledge of mortality experiences may influence the classification, and analyses would have an element of circularity in them. To counter these and other difficulties, there has been developed in France a classification based on type of work, status in the work and type of industry. The groups thus produced are more numerous and cannot easily be socially ranked but they exhibit considerable internal homogeneity. The ECE have recommended a set of groups based on this system.

Study of social class variation in mortality has been immensely productive of testable hypotheses which have led to substantial additions to medical knowledge. For example, much of our understanding of the aetiology of coronary artery disease has derived from original observations on the social distribution of its mortality.

Urban-rural variation:

Urban-rural differences in mortality present a complex but rewarding subject at the intranational level but are at present prohibitively difficult to interpret on the international scale. Although mortality in the most developed countries is generally higher in the urban areas than the rural, this is not true for all causes or at all ages (for example, infant mortality is often higher in rural areas) and it is often quite untrue for the general mortality of developing countries. Urban-rural differences arise from differences in physical environment, occupational differences, economic and social differences and differences in the availability of medical care and nutrition. The direction of differences of these kinds depends on climate, geography and the prevalent levels of social and economic development.

An important problem in the study of urban-rural differences is posed by the possible differences in the quality of certification in urban and rural areas which may arise from differences in the available quality of medical care.

Marital state:

In general, married persons experience more favourable mortality rates than single persons and this is true for both sexes and

all ages. The widowed and divorced have usually the highest mortality of all. Part of the worse mortality of single persons is doubtless attributable to the fact that sufferers from poor health are less likely to marry. In England and Wales, mortality from tuberculosis, rheumatic heart disease and poliomyelitis is higher in single persons and the effect of these conditions on the likelihood of marriage is the probable explanation.

Other diseases which are commoner in single persons are less likely to be due to marriage selection, for example, cancer of the breast and ovaries in women and of the prostate in men.

A disease that is commoner in married women than in single and in widowed and divorces more than in married is cancer of the uterine cervix. This disease is more common in women who have been married more than once and is more common in women whose sexual initiation was early. The likelihood that its occurrence is directly related to sexual activity seems very high.

The generally more favourable mortality experience of the married may stem partly from the stability of nutrition and other habits and partly from the better opportunities for following medical advice in case of illness. In countries with high maternal mortality rates (which usually also have high fertility rates), the mortality advantages of marriage may be offset for women in the child-bearing age. In some countries, the female mortality associated with reproduction is sufficient to offset the generally higher male mortality from all causes. The age at which women achieve numerical equality with male (there are more males at birth in all countries) is an indicator of the safety of reproduction for females and the age at equality may be very late in some developing countries.

Mortality is raised in the recently bereaved and this accounts partly for the high mortality rates of the widowed. This phenomenon is interesting and has been very little investigated. It is of interest that the admission rate to mental hospitals for widowed persons is raised in some countries and this is more marked in those who are widowed young. The effect is most marked in respect of admissions for alcoholism in males and for depression in females.

Data are rarely available on the extent of bereavement and the number of dependants left by deceased. In many countries, data on the numbers of widows and orphans produced by current mortality would be valuable in relation to the development of social policies. There has also been very little analysis of cause of death by marital state.

Causes of mortality:

Although the underlying cause of death may seem an arbitrary and often unreliable piece of information to abstract from the records of a deceased person, the analysis of data on these causes has proved remarkably useful when due regard has been paid to their limitations. The distribution of mortality by cause varies very considerably by age, sex and country. Although the ease with which causes of death may be established also varies with at least age and country and is dependent to a large extent on the quality of available medical care, it is likely that a large part of the variation arises from real variations in morbidity experience.

The United Nations Population Bulletin (No. 6, 1963) has proposed that the available classified data on causes of death might usefully be grouped into five main categories: infectious and parasitic diseases; cancer; cardiovascular disease and bronchitis at ages above five years; violence; and other causes.

As has already been discussed, mortality from infections has been most responsive to the general and specific environmental changes that have spread throughout a large part of the world in the past 150 to 200 years. The enormous majority of mortality from infection is now preventable and the problems of its prevention are problems of the disposition of resources. A few important infectious diseases remain intractable and a world-wide vigilance is needed to contain them.

Cancer is a term embracing a range of conditions of diverse aetiology and behaviour which have in common a disorderly proliferation of tissues which threatens the life of their host. Although most forms of cancer exhibit a marked association of incidence with advancing age, cancer is now—after accidents—the

most important cause of death in children in most developed countries. The basic pathological process in most forms of cancer is essentially an accidental derangement of cell division whose probability of occurrence may be affected by environmental influences. As a result of studies often initiated by examination of mortality data, many of these influences have been identified and the related forms of cancer substantially diminished in frequency by appropriate means of environmental control. In the most important case, that of lung cancer, the relevant environmental influence has been clearly identified but a socially acceptable means of controlling exposure to it is still beyond our capabilities. As a result, lung cancer is almost the only important form of cancer from which mortality is increasing although even for this site the death rates are lower for recent generations in some countries. The treatment of established cases has improved somewhat for most forms of cancer during the past twenty years. For some sites, the improvement has been marked, while in others it has been depressingly small. There is reason to believe that for most sites, a means of earlier diagnosis would be valuable in the further improvement of the results of treatment.

Heart and lung diseases are closely related in that pulmonary embarrassment is a common, fatal end result of chronic heart disease and heart failure frequently complicates the final stages of chronic obstructive lung disease. In the developed countries, the trend in mortality from cardiovascular and lung disease may be summarized as a marked fall during the past fifty years at ages up to 44 years, largely stable rates in the age range 45-64 years and slightly rising rates at ages over 65 years. Certified causes show a fall in the mortality from rheumatic heart disease which seems to account for the falling rates at younger ages, and a remarkable increase in arteriosclerotic heart disease, especially in later life. There are very good reasons for regarding the decline in mortality ascribed to rheumatic heart disease as real—the disease is now rarely encountered in children and young adults in the developed countries and congenital heart disease is now relatively much commoner in these age groups—but the rise in mortality from arteriosclerotic heart disease, and particularly from coronary thrombosis, has often been attributed to changes in diagnostic fashion or diagnostic techniques. Evidence from sources other than mortality statistics suggests that coronary artery disease is commoner than it was formerly in

developed countries and much commoner than in the developing countries at the present time. Although there is now a wealth of evidence relating to the aetiology of coronary artery disease, it cannot be said that this evidence has permitted a clearer account to be given of the pathogenesis of the disease or of the reasons for variations in its reported frequency in different populations and at different times.

Mortality from other heart and lung disease has not shown any consistent tendency to decline but since such disease represents a residual category in mortality certification, it has been subject to the effects of changing diagnostic practices in relation to other forms of heart and lung disease.

Mortality from violence is probably less influenced by trends in diagnostic fashion or precision than that of any other causal group. Although distinctions between the components of the category of violence may reflect national and secular variation in custom, culture and administrative practice, the total category is difficult to confuse with other causes of death.

In countries with long historical series of data, there is little evidence of any change in the over all mortality from violence. There is some small movement between the components of violence, and automobile accidents became an increasingly important cause of death during the first thirty years of the century, although in most developed countries mortality from this cause has increased relatively little in more recent years. Suicide is more commonly reported as a cause of death than formerly and rates show a tendency to be higher in developed countries. Much of the variation in reported mortality from this cause is undoubtedly due to variation in administrative and legal practice. Several studies have shown that in the United Kingdom, for example, many deaths are not officially assigned to this cause even where the medical attendant would privately so assign them.

Mortality from war is an important category within the group of violence. There seems no evidence that we may expect a general decline in mortality from this cause.

Mortality from all other causes has shown a general decline—partly because of the increasing tendency of confident assignment of

deaths to the main groups of causes and partly because the group includes a range of conditions which are influenced by general social and environmental conditions in the way that infections are. The most marked changes have occurred at the younger ages and in the more developed countries.

Among the disease categories worthy of special comment are malaria, tuberculosis and helminthiasis which together must account for the substantial majority of the world's ill-health among children and young adults. In association with precarious or inadequate nutritional levels these three diseases must account for an enormous part of the variation in expectation of life. Malaria is essentially controllable if not eradicable, and relatively inexpensive to deal with. Helminthiasis may become less important as technical developments in waste disposal become more widespread and urbanization develops. Tuberculosis is expensive to deal with but its major decline in the developed countries, well before any medically based preventive or therapeutic measures were available to deal with it, gives grounds for long term optimism. Malnutrition is clearly a much more difficult problem involving the need not only for increased world food production but also for much better facilities for the distribution of food throughout the world. Not only do local famines and local surpluses co-exist in different part of the world but undernutrition and overnutrition simultaneously account for a large part of the world's mortality in different areas.

Methods in Mortality Statistics

Cause of death :

The medical certification of cause of death has, for its original basis, the social need to distinguish death by "natural causes" from death by "epidemic" diseases or by criminal action. The development of epidemiological studies based on statistics of cause of death has led to an increasing sophistication of the concept of cause of death and to elaborate methods for determining the appropriate diagnostic attributions and to classifying the resulting information in a meaningful and comparable way.

The international certificate of cause of death, which is widely used in many countries of the world, seeks to elucidate the fatal

sequence of morbid events and to identify a single pathological process as the initiator of the sequence. It also permits the possibility of recording the presence of other contributory diseases not involved in the "fatal sequence". As adapted for use in some countries, the certificate includes a record of the basis of the opinion on causes (e. g. whether based on autopsy) and if suitably analysed this item may permit evaluation of diagnostic data.

Nevertheless, the concepts of a "fatal sequence" and of an "underlying cause" of death are beginning to lose their relevance as it becomes clearer that death is frequently not easily attributable to an orderly sequence of events. In the developed countries particularly, death is relatively uncommon after the first twenty-eight days of life and before the seventh decade. Outside these limits, multiple pathological processes are common and it is difficult or possibly meaningless to describe their collective contribution to death in terms of a fatal sequence initiated by an underlying cause.

For this reason, and to make maximum use of data recorded on death certificates, various systems have been proposed for coding and tabulating multiple causes of death.

The features of a multiple cause analysis are several. First, it should be possible to rearrange the recorded diagnostic data on certificates so as to remove the difficulty that any actual certified sequence may represent no more than the opinion or even whim of a certifier. National or other beliefs about the relative importances of, or detailed relationships between, diseases currently complicate international comparability of mortality data. Second, it should be possible to examine the occurrence of combinations of conditions other than the relatively few which the use of the ICD "combination categories" permits. Third, it should be possible, for countries where it is useful or desirable, to select readily the principal or underlying cause of death. Fourth, there should exist an appropriate international classification which accommodates the kind of diagnostic data that is relevant to multiple cause analysis and, fifth,, there should be an international certificate of cause of death capable of use in these applications.

It is, first of all, necessary to distinguish between underlying disease processes and their complications or clinical manifestations,

and between conditions believed by the certifier to have contributed to the death and conditions merely known to have been present at the time. Multiple cause analysis would be simpler if conditions not believed to have beeen involved in the death were omitted but it may be argued that their exclusion would be arbitrary and would imply more understanding of the disease circumstances surrounding death than is commonly justifiable.

The recording on a suitably designed death certificate of the relevant diagnostic data in a way which would be consonant with these requirements presents several difficulties. For example, the terms "meningococcal meningitis", "rheumatic endocarditis" or hypertensive heart disease" confound, in each case, an underlying disease process with a particular clinical manifestation or complication capable of independent or other causation, although it would usually seem absurd to the certifier to record these separately as though their specific relationship could not validly be assumed. The separation of underlying process from clinical (or other) manifestation could not easily be performed during the disease-coding process. A certificate which called for the separate recording of underlying processes and particular manifestations would pose problems in relation to conditions such as "perforated gastric ulcer", "subdural haematoma", "status asthmaticus" or even "carcinoma of the bronchus". Research and study of these problems is urgently needed and the experimental and developmental work currently proceeding in the vital statistics offices of several countries is to be encouraged. If, as seems likely, the present form of certificate has outlived its usefulness, it will be important to give intensive consideration to what will replace it.

The analysis of multiple cause data also poses problems. The number of causes recorded will doubtless vary considerably and so the number of recorded conditions will bear no obvious relationship to the number of deceased. Fer this and other reasons, it will probably continue to be desirable to publish some tabulations in which each death is represented by one diagnostic term, whether this be designated the underlying or principal cause of death or not.

Tabulations or reported conditions are difficult with the present certificate, ICD and rules, since two terms on a certificate may be combined by the rules into a single rubric. Cross tabulations of underlying causes against Part II Conditions are also difficult because present rules often select a Part II term as the whole or part of the underlying cause of death. A possibly useful system using the present death certificate would involve the suspension of all selection rules and the selection of the last mentioned term in Part I as the underlying cause. Cross tabulation of this term with the first mentioned term would represent an examination of the modes of dying associated with underlying conditions while cross tabulation with one term of Part II would represent an examination of important disease associations. To the extent that certifiers used (or could use) the present certificate as was intended, such analyses would be useful.

In a certificate in which the underlying cause concept was abandoned and the significant diagnostic terms merely listed, clustering of disorders could be identified by appropriate statistical methods and their possible significance investigated. If the problems of isolating unitary conditions can be solved and a suitable classification of such terms devised, this approach would clearly be very valuable. These problems may be commended to the attention of those responsible for the next revision of the ICD.

Statistical methods appropriate to such analyses are currently receiving intensive attention in the general context of the application of computers to problems of taxonomy. A variety of methods is available for detecting clustering in correlation matrices.

For a general discussion of problems of multiple cause analysis reference may be made to the proceedings of a Conference on Multiple Cause Analysis, held on 9 and 10 May 1967 at the General Register Office for England and Wales in London.

Analysis of age specific mortality:

Age is far the most important determinant of the level of general mortality and many individual diseases occur and kill more commonly as age advances. It is not surprising, therefore,

that analysis of mortality rates has frequently been concerned with the association with age.

Provided that the groupings are not too coarse, mortality rates specific for age groups describe mortality as a function of age in a given population at a given time. A historical series of such age specific rates will describe the way in which this function has changed with the passage of time. What a set of age specific rates does not necessarily provide is a description of the way the risk of dying changes in the course of human life. For example, a set of age specific rates for lung cancer mortality calculated from current mortality and current population age distribution at any time in the past thirty years or so in developed countries would show a peak mortality at about sixty years and lower rates at both younger and older ages. In aetiological terms, cancer risk as a function of age would be very difficult to explain if there were really a fall-off at the later ages.

If a set of age specific rates is available at secular intervals corresponding to the class intervals or the age distribution, the rates may be set out as a two dimensional table with age as one dimension (for example, distinguishing the columns) and the secular intervals as the other (distinguishing the rows). Such a table may be informatively examined in three ways, two of which are quite obvious. If successive rows are examined, the secular changes in the age distribution are seen; if columns are examined, the secular trends in rates at particular ages are seen. If, however, the diagonals of the table are examined, each diagonal set of cells will represent the rates of a generation of individuals passing simultaneously through historical time and human life.

A method of deriving similar generation data using annual, single year age groupings and combining them into quinary-quinquennial cohorts of mortality rates has been used extensively in recent years. The method has permitted the resolution of a number of problems arising from apparently anomalous functions relating disease and age, especially in relation to cancer and to tuberculosis. If differences between generations are greater than between members of the same generation at ages separated by the same time span as that between the generations, distortions may occur of the current

rates as a function of current population age distribution. It is now clear that the narrative use of age specific mortality data must involve examination of such cohort or generation data if it is to avoid being misleading.

Ordinary life table techniques have been extensively used as a means of comparing mortality rates independently of age. The so-called expectation of life at birth (the mean duration of life beyond birth in a hypothetical population subject to a particular set of age specific mortality rates) provides an age-independent mortality index which is dramatically responsive to the influence of early mortality. It is unfortunately very open to misinterpretation since it represents the mean of a usually very bimodal distribution, and also seems to imply a prediction of life duration for the current population of newborn.

Life tables based on cohort data bear more resemblance to reality in that they summarize the life experience of actual generations, but they are obviously of little use in comparisons of current mortality.

Perhaps the most important quantity in a life table is the column of 1_x values which represents the attenuation of a population subjected to the mortality rates being used. Graphical representation of the column of 1_x values clarifies the effect of the age differences in mortality. Unfortunately, the use of 1_x values for multiple comparisons is usually clumsy. It has been suggested that the additional use of the modes of the distribution of age duration would represent a more informative and less misleading summary than the expectation of life. There certainly seems much to be said for further development of life table methods for mortality analysis.

Record linkage:

The linkage of two or more records pertaining to an individual or of records pertaining to related individuals has for long been a common place of epidemiological and genetic inquiry. The need to link records arises for example where longitudinal experience is being studied or where the use of multiple sources of ascertainment might otherwise undesirably lead to multiple inclusion of individuals in a

study. Recent intense interest in the subject arises from the new possibilities of using automatic data processing machines to effect linkages economically on a very large scale, even in cases where the identifying data may contain errors or inconsistencies.

Where records are usually identified by personal numbers and where these numbers may easily be obtained accurately from the individuals they identify, the problems of liking records are not very great. The problems of assembling a variety of different kinds of records and maintaining them in a single file may well be much greater. The absence of numerical identification of members of the public further complicates linkage where this is usual. Nevertheless, the main requirements for linkage of the usual kinds of vital registration and morbidity statistical data at national level have now been clearly stated and the major problems have been satisfactorily solved. The decision to carry out analyses of linked data at national level is now governed by administrative and political rather than methodological considerations.

Simple linkage of birth and death records for infants and children is easy to effect with only modest resources of data processing equipment. It is also relatively easy to link death records for members of the same fraternities for simple genetic or other familial analysis. More elaborate linkages will usually require electronic computers and some investment in document redesign and computer programmes, but basic linkage software is now available from several sources. More complex linkage systems relate to fields other than mortality statistics but they will eventually facilitate the analysis of mortality data in relation to items of data recorded at the time of their occurrence.

The advantages of record linkage are not limited to the increased scope they afford to statistical analysis of mortality data; linkage will usually permit a simplification of data recording since if information may be retrieved from a linked system each item need be recorded only once. For example, it would be unnecessary to record age at death if the date of death and of birth were recorded on the relevant documents, It would be unnecessary to record maternal age, birth order, weight at birth, etc., for infant deaths if these items were already on the birth record which could be linked to that of the death.

Some of the objections to record linkage have been based on the dangers of breaches of confidentiality of records, or of their providing too comprehensive an account of individuals' lives at governmental level. Safeguards against such dangers are now technically possible and adequate systems of safeguards can usually be devised for any particular application. Public acceptance of linked systems may depend crucially on the availability of such devices.

The use of electronic computers :

Electronic computers, although in principle they are no more than a means for speeding data handling and computation, are likely to transform routine and special mortality statistical analysis.

Their most obvious effect should be to speed the production of periodic analyses and reports. The utility of statistical analyses is often largely dependent upon the timeliness of their availability, and mortality statistics are frequently unavailable untill several years after the period to which they relate.

Computers will also influence the degree of reduction of data that is possible. Calculation of informative and succinct indices may involve an amount of computation that is prohibitive if conventional methods are used but wholly practicable with electronic computers. In addition, indices of dispersion may easily be added; for example, the standard deviations of distributions as well as their means and coefficients of variation as well as their informative statistics.

The statistical efficiency of the methods employed may be changed by computers. Many of the present methods were developed in the context of clerical calculation and are not theoretically ideal. A nearer approximation to the ideal may become possible and may encourage the mathematical exploration of more rigorous methods. Reference has already been made to multivariate regression methods in dealing with data involving a wealth of possibly related variates. The methods are impracticable using conventional clerical computation.

The development of automatic "on-line" analysis for monitoring continuously received data also depends on the availability of

processing devices capable of implementing them. Even simple methods (such as cumulative sum techniques) require more elaborate resources that clerical computation can readily provide.

An application of computers that is currently of great interest is the automatic classification and coding of diagnostic data. A complete solution of the problems currently being encountered in this field would be greatly facilitated by changes in the forms of certification and in the disease classification, but the changes need not be extensive and might be beneficial in other respects.

An important use of electronic computers concerns the automatic checking of plausibility of data by examining items tor mutual incompatibility. For example, diagnoses may be checked against sex and age, and unplausible combinations set aside for verification.

Statistical techniques:

Traditionally, the application of elaborate statistical methods to mortality data has characterized demographic rather than public health studies. Recently, an increasing sophistication of method has developed in public health statistical work.

Mention has already been made (5.1) of the use of techniques for examination of correlation matrices in the study of disease associations. Discriminant function and principal component analysis have been applied to these and other problems in mortality associations. Such techniques depend on the availability of quite powerful computing resources but are undoubtedly interesting as an example of future trends in analysis.

A simpler application that is nevertheless of considerable practical interest is the application of methods developed in the context of industrial quality control to the problems of monitoring data as they become available for the early detection of undue peaks of occurrence. Cumulative sum techniques are particularly suitable for simple computer analysis of regularly available data. They involve no more than the accumulation of the differences (positive or negative) between the periodic numerical frequencies of an event and

a suitably chosen base level and the testing that this cumulative sum has remained between limits which can be adjusted to the required sensitivity of the procedure. A change in the underlying mean frequency about which the periodic frequency is varying will be marked by a systematic trend in the cumulative sum, which will thus soon cross one of the imposed limits. The crossing of the limit thus constitutes an alarm signal which can serve to draw attention to the associated change in underlying frequency.

Such a method necessitates the frequent inputting of accruing data to the analysing process. The traditions of offices devoted to the analysis of mortality data often involve the slow accumulation of data and their infrequent (e. g., annual) analysis in bulk. The application of mortality data as monitoring information calls for a much more "on line" analysis.

Another statistical technique that has been very little exploited by health statisticians is multivariate regression analysis. The elimination of unwanted variation has usually been accomplished by simpler methods such as standardization or the use of standardized indices, such as the Standardized Death Rate or Standardized Mortality Ratio. These techniques are extremely useful for the elimination of one or two unwanted sources of variation but the more elaborate data now often available cannot so acceptably be handled in these simpler ways.

The analysis of samples of data is sometimes desirable when the bulk of large scale data prohibits intensive analysis or, in developing countries, where larger scale data may be unobtainable. It is often possible to obtain additional data on samples of deaths. The use of complex stratified samples, dictated by many considerations, has imposed the need for new methods of deriving sampling errors and new methods of estimation and significance testing. Such methods are increasingly being developed but their adoption has so far been very limited. Although some countries disseminate their findings in these fields quite widely, effective communication does not always seem to have been achieved.

Projection of mortality trends has again been more a feature of demographic analysis than of public health applications.

Projections, like all predictions, require qualification but it is possible to specify quite clearly a range of plausible assumptions on which projections of mortality trends might be based. This is a field where public health statisticians and demographers might usefully collaborate.

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Specific reference to the literature has been deliberately avoided in this paper but a bibliography of some of the more important work on mortality statistics is given below.

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Impact of Changes in Mortality

Impact of Prevention of Selected Causes of Death on Life Expectancy: A Methodological Study Based on Rajasthan Data

G. Ramakrishna and M. V. Raman

Levels and Trends in Mortality

During the last three decades or so there had been a decline in the death rates in many parts of the world. This decline had been most rapid in the developing countries brought about largely by advances in therapeutic and preventive medicine rather than by any significant rise in the standard of living. With the present knowledge of medicine and public health it has been possible to effectively neutralize the environment to some extent. The rapid decline in the death rate during 1951-61 in India is a case in point.

It may be remembered that the crude death rate is only a rough measure of the actual force of mortality in a population, its main disadvantage being its heavy dependence on the age structure of the population. A more useful measure which overcomes this difficulty is the expectation of life at birth which is a function of the death rates independent of the age structure of the population.

Sex and Age Patterns of Mortality

For most disease conditions the susceptibility of the two sexes appears to be equal but for some it is different. The difference may be due to a variety of causes. Broadly speaking, at birth and in the first year of life, the female death rate tends to be less than that of the male in most societies, regardless of their development. This female superiority continues for another 2 or 3 years, but thereafter the pattern of differences depends on the overall mortality level. In many countries with high levels of mortality, females are seen to be associated with higher mortality than men up to the age of 40 or so.

Thereafter females have a better chance of survival. It has also been observed that females as a rule, experience unfavourable mortality experience in predominantly agricultural and less developed communities. This may be partly explained by the low status of women and the stress and mortality associated with child-bearing in such communities. Cultural factors and their influence on diet and relative care of girls versus boys have a great deal to do with the relative mortality of males and females.

Causes of Death

Cause of death statistics do not adequately reflect the actual morbidity situation of a population as fatality rates vary widely among the diseases. Consequently, the utility of cause of death statistics for indicating precisely the health or illness situation of a population is correspondingly restricted. However, significant changes in the death rate for a given disease, broadly reflect similar changes in trends in the incidence of that disease. Therefore, in the absence of adequate and reliable statistics on morbidity, the collection of which involves innumerable difficulties, recourse is often made to mortality data for an assessment of health problems and for the development of public health programmes. However, a meaningful analysis is impossible with the extremely unsatisfactory nature of the cause of death data available in this country. But a promising start has been made in areas like Rajasthan, West Bengal, Nagpur, Poona, Bombay, etc. to improve the recording of the cause of death. For drawing general conclusions the adoption of broad groups of causes may be desirable as this may further reduce inaccuracies in recording.

Mortality due to infective and parasitic diseases has gone down considerably in the developed countries. In the developing countries also in recent years there has been marked improvement in mortality due to specific diseases like malaria, enteric and diarrhoeal diseases, etc. As stated earlier this improvement in mortality is largely the outcome of the application of modern medicine and extensive public health measures and not of any significant advances in the standard of living. Even though in India the decline in mortality due to infective and parasitic diseases has been quite rapid since World War II, there is scope for further decline. Such

reductions will be meaningful only if there is also improvement in the standard of living of the population without which it may be difficult to maintain the progress. In India, apart from the contribution to mortality by the infectious and parasitic diseases, nutritional deficiency is another important factor contributing directly or indirectly to excessive mortality. If the present day attempts to improve the agricultural output by the Green Revolution succeed and if the price line of the essential consumer commodities could be held, the problem of undernourishment could be more firmly tackled.

Assuming that it would be possible to control the above mentioned diseases by taking appropriate steps, one may be interested to know to what extent there could be improvement in the health status of the population. While the improvement cannot be precisely measured this may be attempted by estimating the gains in life expectancy that may accrue with the complete or partial elimination of these causes of death. This problem of the effect on life expectancy of improvement in mortality had been studied earlier by M. N. Karn (1933), C. Chandrasekhar (1949), K. W. Kimball (1958), C. L. Chiang (1960) and so on. In the present discussion the formula derived by Chiang for estimating the probability of death when a particular cause is eliminated completely has been suitably extended to cover situations when only partial elimination is envisaged. The paper confines itself to the analysis of data from Rajasthan. The procedure adopted has been briefly explained below.

Method

The following symbols are used in this paper. There are 'c' causes of death and $k = 1, 2, \ldots\ldots c$ and l_x, p_x, q_x, μ_x and e_x^o are the usual life table functions.

Q_{xk} = probability of dying in the interval $(x, x+1)$ due to cause k when all other causes are present.

ν_{xk} = force of mortality of a particular cause k.

$q_{x \cdot k}$ = probability of dying in the interval $(x, x+1)$ when cause 'k' is eliminated as a cause of death.

α is a constant taking any value in (0, 1)

$_\alpha q_{x\cdot k}$ = probability of dying in the interval $(x, x+1)$ when cause k, at level $\alpha\nu_{x+t,\,k}$ is eliminated completely.

$_\alpha \overset{o}{e}_{x\cdot k}$ = expectation of life at age x when cause k at level $\alpha\nu_{x+t,\,k}$ is eliminated completely.

It can be shown that $\mu_{x+t} = \sum_{k=1}^{c} \nu_{x+t,\,k}$ when the death of a person is assigned to a single cause of death where $0 < t \leqslant 1$.

If we assume that

$$\frac{\nu_{x+t,\,k}}{\mu_{\ +t}} \text{ is constant for } 0 < t \leq 1$$

it can be shown that $\dfrac{\nu_{x+t,\,k}}{\mu_{x+t}} = \dfrac{Q_{xk}}{q_k}$

and $q_{x\cdot k} = 1 - p_x\ (q_{x-}\ Q_{xk})/q_x$

Now if the force of mortality due to a particular cause k, $\nu_{x+t,\,k}$ decreases to $\alpha\ \nu_{x+t,\,k}$ then any of the following may happen.

(1) Only the total force of mortality μ_{x+t} changes to μ'_{x+t}

i. e. $\mu'_{x+t} = \sum_{\substack{i=1 \\ i\neq k}}^{c} \nu_{x+t,\ i} + \alpha\, \nu_{x+t,\ k}.$

(2) μ_{x+t} does not change and others may change

i. e. $\mu_{x+t} = \sum_{\substack{i\neq k \\ i=1}}^{c} \nu'_{x+t} + \alpha\ \nu_{x+t,\ k}.$

(3) μ_{x+t} and others change

i. e. $\mu''_{x+t} = \sum_{\substack{i=1 \\ i\neq k}}^{c} \nu''_{x+t,\ i} + \alpha\, \nu_{x+t,\ k}.$

The gain in expectation, when the force of mortality due to a particular cause k decreases to $\alpha \nu_{x+t,\,k}$, is estimated as shown below :

Assumption (1) :

p'_x and μ'_x are the life table functions when the force of mortality due to a particular cause has decreased.

$$\text{Let } \frac{\mu'_{x+t}}{\mu_{x+t}} = \beta \text{ (a constant)}$$

$$\text{then } p'_x = \exp - \int_0^1 \mu'_{x+t}\, dt = p_x^{\beta},$$

$$\mu_{x+t} - \mu^1_{x+t} = (1-\alpha)\, \nu_{x+t,\,k}$$

$$p'_x = \exp - \int_0^1 \mu_{x+t}\, dt \, . \, \exp \int_0^1 (1-\alpha)\, \nu_{x+t,\,k}\, dt$$

$$= p_x^{1-(1-\alpha)Q_{xk}/q_x}$$

From the above it is clear that

$$\beta = 1 - \frac{(1-\alpha)\ Q_{xk}}{q_x}$$

$$^{\alpha}q_{x.k} = 1 - \exp - \int_0^1 (\mu'_{x+t} - \alpha \nu_{x+t,\,k})\, dt$$

$$= 1 - p_x^{\beta - \alpha Q_{xk}/q_x}$$

when we substitute the value of β we get

$$^{\alpha}q_{x\cdot k} = 1 - p_x^{1 - Q_{xk}/q_x}$$

Let $'\overset{o}{e}_x$ be the expectation of life at age x when the force of mortality is μ'_x. The gain in expectation at age x when cause k at leve $\alpha \nu_{x+t,\,k}$ is eliminated completely is $'\overset{o}{e}_{x\cdot k} - {'\overset{o}{e}_x}$. The gain in

expectation of life at age x due to a decrement in the force of mortality of cause k from $\nu_{x+t,\,k}$ to $\alpha\nu_{x+t,\,k}$ is

$$('\overset{o}{e}_{x\,k} - \overset{o}{e}_{x}) - ('e_{x\cdot k} - '\overset{o}{e}_{x}) = ('\overset{o}{e}_{x} - \overset{o}{e}_{x}) .$$

Assumption (2):

$$\overset{\alpha}{q}_{x\cdot k} = 1 - \exp - \int_{o}^{1} (\mu_{x+t} - \alpha\nu_{x+t,k})\, dt$$

$$= 1 - \exp - \int_{o}^{1} \mu_{x+t} dt \, . \, \exp \alpha \int_{o}^{1} \nu_{x+t} dt$$

$$= 1 - p_x^{\,1 - \alpha\, Q_{xk}/q_x}$$

The gain in expectation is

$$('e^{o}_{x\cdot k} - e^{o}_{x}) - ({}^{\alpha}e^{o}_{x\cdot k} - e^{o}_{x})$$

$$= \ 'e^{o}_{x\cdot k} - {}^{\alpha}e^{o}_{x\cdot k}.$$

Assumption (3):

As in assumption (1) we have

$$p'_x = p_x^{\beta} \text{ and } {}^{\alpha}q_{x\cdot k} = 1 - p_x^{\,\beta - \alpha\, Q_{xk}/q_x}$$

Here ${}^{\alpha}q_{x\cdot k}$ does not reduce to $1 - p_x^{\,1-\alpha\, Q_{xk}/q_x}$

since β does not depend on α. We have to choose values for β when α is fixed to find ${}^{\alpha}q_{x\cdot k}$

The gain in expectation is

$$('e^{o}_{x\cdot k} - e^{o}_{x}) - ({}^{\alpha}e^{o}_{x\cdot k} - 'e^{o}_{x})$$

The above formulae can be suitably extended to the age groups (x, x + n) if n is not large.

Data

The analysis is done for Rajasthan using the registration data of 1964. The causes of death considered are:

(1) Infective and Parasitic diseases together with allergic, endocrine system, metabolic and nutritional diseases for males and females separately.

(2) Deliveries and complications of pregnancy, child birth and puerperium for females

$$_nQ_{xk} = \frac{_nD_{xk}}{N_x}$$

where $_nD_{xk}$ = deaths due to a particular cause k in (x,x+n).

N_x = Total population at age x.

$$_nQ_{xk} = \frac{_nD_{xk}}{_nD_x} \cdot \frac{_nD_x}{N_x} = \frac{_nD_{xk}}{_nD_x} \cdot {_nq_x}$$

If we assume that underregistration is to the same extent for all the diseases then $\frac{_nD_{xk}}{_nD_x} = \frac{_nR_{xk}}{_nR_x}$

where $_nR_{xk}$ = registered deaths due to cause k in (x, x+n)

and $_nR_x$ = registered deaths in (x, x+n).

Using these values $_nQ_{xk}$ we can find $\alpha\ {_nq_{x \cdot k}}$ for age groups 0—1, 1—4, 5—9, 10—14 .... 55—59.

The values beyond 60 are extrapolated by using Makeham's formula.

The values of $\alpha_{q_{x \cdot k}}$ are found when α = 0.25, 0.50, 0.75 and 1.00 using assumptions (1) and (2) only.

Results

The gain in expectations of life for various values of α has been estimated and shown in Tables 1, 2 and 2 (a).

Table 1

GAIN IN EXPECTATION OF LIFE FOR MALES WHEN CAUSES OF DEATH (002 – 138) AND (240 - 289) ARE ELIMINATED

Age		Assumption (1)			Assumption (2)		
x	$\alpha=1.00$	$\alpha=0.75$	$\alpha=0.50$	$\alpha=0.25$	$\alpha=0.75$	$\alpha=0.50$	$\alpha=0.25$
0	4.15	3.05	2.02	1.00	3.15	2.13	1.09
1	3.59	2.66	1.75	0.87	2.72	1.84	0.93
5	3.16	2.34	1.54	0.77	2.39	1.62	0.82
10	2.41	2.09	1.38	0.68	1.73	1.03	0.32
15	2.64	1.96	1.29	0.63	2.01	1.35	0.68
20	2.44	1.81	1.20	0.59	1.85	1.24	0.63
25	2.23	1.65	1.09	0.54	1.69	1.14	0.58
30	1.99	1.48	0.98	0.48	1.51	1.01	0.51
35	1,64	1.22	0.80	0.39	1.25	0.84	0.42
40	1.28	0.95	0.63	0.31	0.97	0.65	0.33
45	0.95	0.70	0.47	0.23	0.72	0.48	0.25
50	0.82	0.61	0.40	0.20	0.62	0.42	0.21
55	0.58	0.43	0.28	0.14	0.44	0.30	0.15

002 — 138 : Infective and parasitic diseases.
240 — 289 : Allergic, endocrine system, metabolic and nutritional diseases.

Table 2

GAIN IN EXPECTATION OF LIFE FOR FEMALES WHEN CAUSES OF DEATH (002—138) AND (140—189) ARE ELIMINATED

Age		Assumption (1)			Assumption (2)		
x	$\alpha=1.00$	$\alpha=0.75$	$\alpha=0.50$	$\alpha=0.25$	$\alpha=0.75$	$\alpha=0.50$	$\alpha=0.25$
0	4.39	3.21	2.10	1.03	3.36	2.29	1.18
1	4.57	3.35	2.19	1.07	3.50	2.38	1.23
5	3.93	2.87	1.88	0.92	3.01	2.05	1.06
10	3.57	2.61	1.71	0.84	2.73	1.86	0.96
15	3.34	2.44	1.59	0.78	2.56	1.75	0.90
20	3.12	2.28	1.49	0.73	2.39	1.63	0.84
25	2.91	2.12	1.39	0.68	2.23	1.52	0.79
30	2.57	1.87	1.23	0.60	1.97	1.34	0.70
35	2.23	1.64	1.07	0.53	1.73	1.19	0.62
40	2.01	1.45	0.95	0.47	1.54	1.06	0.56
45	2.07	1.60	1.19	0.39	1.68	1.27	0.47
50	1.16	0.83	0.55	0.27	0.89	0.61	0.33
55	0.93	0.65	0.43	0.21	0.72	0.50	0.28

002 — 138 : Infective and parasitic diseases.
140 — 189 : Allergic, endocrine system, metabolic and nutritional diseases.

Table 2 (a)

GAIN IN EXPECTATION OF LIFE OF FEMALES WHEN CAUSES OF DEATH (640—689) ARE ELIMINATED COMPLETELY

Age		Assumption (1)			Assumption (2)		
x	$\alpha=1.00$	$\alpha=0.75$	$\alpha=0.50$	$\alpha=0,25$	$\alpha=0.75$	$\alpha=0.50$	$\alpha=0.25$
0	1.98	1.47	0.97	0.48	1.50	1.01	0.51
1	2.23	1.66	1.09	0.54	1.69	1.14	0.57
5	2.40	1.78	1.17	0.58	1.82	1.23	0.62
10	2.46	1.83	1.20	0.60	1.86	1.26	0.63
15	2.49	1.85	1.22	0.60	1.89	1.27	0.64
20	2.38	1.77	1.17	0.58	1.80	1.21	0.61
25	1.99	1.48	0.98	0.48	1.51	1.01	0.51
30	1.62	1.21	0.80	0.40	1.22	0.82	0.41
35	0.96	0.71	0.47	0.23	0.73	0.49	0.25
40	0.45	0.33	0.22	0.11	0.34	0.23	0.12
45	0.09	0.06	0.04	0.02	0.07	0.05	0.03

640 — 689 ; Deliveries and complications of pregnancy, child birth and puerperium.

The gain in life expectancy for males at age 0 if deaths due to infective, parasitic, nutritional and allied diseases classified in the same group are completely eliminated is about 4.15 years whereas the corresponding gain for West Bengal observed in an earlier study is 7.86 years. The higher value for West Bengal is obviously due to the greater mortality from these causes compared with other causes in the State. When α takes values 0.75, 0.50 and 0.25, the gains in expectations of life at age 0 under Assumption (1) are 3.05, 2.02 and 1.00 years and under Assumption (2) are 3.15, 2.13 and 1.09 years. The more plausible values are obtained under Assumption (3) and may lie in the intervals (3.05, 3.15), (2.02, 2.13) and (1.00. 1.09) for the various values of α mentioned above.

For females, the gain in life expectancy at age 0 if deaths due to the above set of causes are eliminated is 4.39 years whereas the comparable figure for West Bengal is 7.12 years. Further, the gain in life expectancy at age 0, when deaths due to deliveries and complications of pregnancy, childbirth and puerperium are completely eliminated is 1.98 years which is very similar to that for West Bengal (1.70 years). The maximum gains in Rajasthan and West Bengal are at age 15, the values being 2.49 and 2.46 years respectively.

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Effect of Changing Mortality and Fertility on the Population of Kerala, 1971

R. Ramakumar

Introduction

It is well known that declining mortality without a corresponding decrease in fertility not only precipitates an accelerated growth of population but increases the proportion of persons in the economically unproductive age groups[1]. Kerala's population has been recording a steady increase in mortality for the past two decades[2]. But whether there was an accompanying decrease in fertility in recent times is not quite certain. This uncertainty leaves a wide gap in the knowledge of the age structure of the population. Planning and administration in the economic, educational, health and social service fields will not bring forth full benefits unless the composition of the population is taken into account[3].

A number of demographic factors influence the age composition of a population[4]. The initial level of mortality, the degree and pattern of change in mortality at the various ages and changes in the levels of fertility are some of them. There are analytical studies which provide the various possible effects associated with the variations in the factors mentioned above[5]. But only an empirical study can throw light on the specific changes that may be brought about in a given population. It is such a study which can provide a basis for investigating the possible consequences due to the changed structure. It is not known whether the projected figure of 21.7 million as the population of Kerala in 1971, given in the Economic Review of Kerala, has been arrived at after taking into consideration the factors mentioned earlier[6]. Further, a decline of birth rate from 38.9 in 1961 to 35.4 in 1971 and a decline of death rate from 16.1 to 10.1 during the same period resulting in a growth rate of 28.4 per cent during the decade and an expectation of life at birth equal to 56

years for males and 60 years for females given there appears to be unrealistic based on other evidences.[7]

In this paper an attempt is made to study the influence of the changes in mortality and fertility on Kerala's age structure during the decade 1961–1971. The method of approach is to estimate the 1971 population of Kerala under different assumptions of decline in mortality and compare the resultant age structure with that of 1961.

Population of Kerala, 1971

The final returns of the 1971 Census of population of Kerala is not expected to be available before the end of this year. Hence the 1971 age structure of Kerala is estimated. During the past decade nothing extraordinary has happened which could have brought about violent changes in the demographic determinants of the population of Kerala. The decline in mortality noticed in the previous decade (1951–1961) can be reasonably assumed to be continuing. Although there are no concrete evidences to indicate a decline in fertility, small decreases are likely due to the widespread family planning propaganda. Net migration is assumed to be negligible.

Projections in mortality have to take into consideration the following generalisations:

i. "The measure of mortality that determines the effect of changes in mortality on age composition and growth is the relative changes in survival rates, rather than the relative changes in the corresponding mortality rates."[8]

ii. That the improvements in mortality rates are linear when the expectation of life at birth is below 60 years[9].

In what follows is detailed how the Regional Model Life Tables of Coale and Demeny[10] are made use of for arriving at reasonable survival ratios for mortality projections.

The available life tables of Kerala[11] for the previous decades upto1961 are subject to gross abnormalities. The method suggested by Namboothiri[12] is made use of for arriving at a suitable set of

survival ratios. But Regional Model Life Tables were made use of instead of the U. N. Model Life Tables. Using the "West" model the mortality level corresponding to each of the age specific survival ratios of all the existing life tables were interpolated. The levels* did not show an uniform increase (i. e., a decline in mortality) over time or cohortwise. The gross misreporting of age has resulted in a pattern of successive gains and losses in the mortality levels when changes in mortality are studied on a cohort basis. The changes over time for each age group on the other hand show a smoother decline in mortality or gain in mortality levels. Further, there was a pattern in the levels of mortality that was common for all the inter-censual periods. It was interesting to note that mortality levels for ages 5-9 was consistantly lower than that of 0-4 years. The levels showed an increase from 10-24 years and then declined upto 60 years and thereafter increased once again though slowly. The exceptions to this pattern were few. See Table 1.

Table 1

THE MORTALITY LEVELS CORRESPONDING TO THE SURVIVAL RATIOS OF THE OFFICIAL LIFE TABLES, TAKEN FROM THE "WEST" REGIONAL MODEL LIFE TABLE, OF COALE & DEMENY AND THE ESTIMATED LEVELS FOR 1961 — 1971

Age	Males Intercensual Periods				Females Intercensual Periods			
	1931–1941	1941–1951	1951–1961	1961–† 1971	1931–1941	1941–1951	1951–1961	1961–† 1971
0–4	7.33	10.27	13.19	16.0	8.65	10.98	13.57	16.0
5–9	–0.73	7.61	11.32	15.0	3.86	6.30	14.08	20.0
10–14	3.57	11.11	14.90	18.0	4.89	12.42	18.63	23.5
15–19	9.40	13.65	17.28	20.5	5.54	16.69	18.88	23.5
20–24	8.05	12.45	15.78	18.5	4.65	14.51	15.80	18.0
25–29	6.30	10.57	14.26	16.0	4.45	12.01	15.01	17.5
30–34	6.43	9.39	13.13	15.0	5.11	10.44	13.21	15.5
35–39	6.31	8.68	11.22	12.5	5.44	8.37	10.13	11.5
40–44	5.69	7.64	9.17	10.0	4.28	6.55	8.75	10.0
45–49	3.82	6.55	7.89	9.0	2.73	5.17	7.32	9.0
50–54	2.11	5.67	6.44	7.0	0.90	2.26	5.67	7.5
55–59	0.99	5.29	5.47	6.0	0.74	2.61	6.74	9.0
60–64	0.48	9.76	5.70	7.0	0.55	3.36	8.15	10.5
65–69	–0.03	3.46	6.10	7.5	1.02	4.49	10.99	15.0
70–74	0.11	7.02	7.75	8.0	1.62	5.57	12.29	17.0
75+	–1.88	17.20	17.20	18.0	1.99	11.02	24.00	20.0

† Estimates.

* Hereafter 'levels' shall refer to the 'mortality levels' given in the *Regional Model Life Tables and Stable Populations*, of Coale and Demeny.

Because of the consistant pattern described above and because of the wide variations in the levels, it was thought unwise to choose the median level of the first nine age groups as the mortality level of the population itself, as suggested in the U. N. Manual[13]. Thus choosing the mortality level for population projection on the assumption of declining mortality became difficult. A compromise level had to be chosen for each age group that was commeasurable with the time trend, cohortwise gains and the overall agewise pattern of mortality at each time point. Extrapolations were made on the basis of linear increase in mortality levels with regard to time. Cohortwise levels were fixed for each cohort on the assumption that gains in the level of mortality for each cohort through decades would follow a second degree curve. The levels arrived at in this fasion for each age group were very close in almost all cases. Average of the different levels so arrived at for each age group was taken as the level of mortality for that age group for the decade 1961-1971.*

The number of births during the intercensual period of 1961 to 1971 was obtained using the age specific fertility rates estimated by Namboothiri for 1961.[14] The same source also provided some idea as to the trend, if there could be any in the decline in fertility. Linear extrapolation was adopted to estimate a new set of fertility rates that would register an overall decline in the birth rate.

Using the set of survival rates and fertility rates obtained in the manner described above four different estimates of the population of Kerala, 1971 were calculated under the following assumptions:

(a) Mortality and fertility remained constant since 1961.

(b) Mortality declined steadily since 1961 but fertility did not.

(c) Mortality declined steadily since 1961 and fertlity declined after 1966.

(d) Mortality and fertility declined steadily since 1961.

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*Since the survival ratios given in the Model Life Tables are for 5 year periods the estimates for 1971 were obtained at two stages, taking care to see that the decline in mortality is uniform for the period.

The percentage age distribution and the total population of Kerala, 1971, under the four assumptions are given in Table 2.

Table 2

PER CENT AGE DISTRIBUTION AND TOTAL POPULATION OF KERALA 1961 AND THE ESTIMATED FIGURES OF 1971, UNDER THE FOUR ASSUMPTIONS — (a), (b), (c), & (d)

Age	1961	1971 (a)	(b)	(c)	(d)
0–4	14.95	16.22	16.64	16.25	15.95
5–9	14.46	13.47	13.57	13.63	13.37
10–14	13.23	10.60	11.11	11.17	11.25
15–19	8.48	11.26	11.09	11.14	11.23
20–24	8.49	10.39	10.20	10.25	10.33
25–29	7.64	6.56	6.47	6.50	6.55
30–34	6.35	6.46	6.36	6.39	6.44
35–39	5.98	5.72	5.64	5.66	5.71
40–44	4.45	4.62	4.53	4.56	4.59
45–49	4.21	4.16	4.09	4.10	4.14
50–54	3.31	2.92	2.89	2.90	2.93
55–59	2.62	2.57	2.53	2.54	2.56
60–64	2.23	1.83	1.79	1.80	1.81
65–69	1.45	1.27	1.26	1.27	1.28
70–74	1.01	0.92	0.93	0.93	0.94
75–79	0.64	0.48	0.50	0.50	0.51
80+	0.50	0.55	0.40	0.41	0.41
Total	100.00	100.00	100.00	100.00	100.00
Population	16,903715	21,047856	21,629747	21,530871	21,358493

Growth Rate :

The decade of 1951-1961 saw the population of Kerala increasing by 24.76 per cent. Since then death rate has declined. There are some chances that birth rate has also declined though not considerably enough to slow down the rate of growth. The intercensual growth under the four sets of estimates is given in Table 3. Excepting for the situation where mortality and fertility have remained constant, the rates of population growth are higher than that of the previous decade. Even with a steady decline in fertility along with the decline in mortality the rate of growth has shown

Tabe 3

VARIOUS RATES 1961–'71 CALCULATED UNDER THE FOUR ASSUMPTIONS AND THE PREVAILING RATES OF 1961

Rate	1961	Estimates (a)	(b)	(c)	(d)
Rate of Growth during the decade/100	24.76	24.52	27.96	27.37	26.35
Inter censual Birth Rate/1000	38.9	39.36	39.00	38.53	37.67
Inter Censual Death Rate/1000	16.1	14.84	11.04	11.16	11.32
Child (0–4 yrs) Death Rate/1000	—	142.2	113.66	113.80	113.79
Expectation of Life at Birth					
Males	44.16	—	50.0	50.0	50.0
Females	50.00	—	55.67	55.67	55.67
Number of Males per 100 Females	97.89	96.57	97.14	97.11	97.07

only an increase. But a steady decline fertility spread over the whole decade is unlikely. It may be reasonable to assume that mortality decline has been continuous for the whole decade and that fertility decline might have set in by the middle of the decade; in which case the Kerala population would have increased by 27.37 per cent during the decade to reach a total of about 21.5 million in 1971.

Vital Rates

The overall effect due to improvements in the survival rates show a decrease in the death rates from about 16 per thousand in 1961 to 11 per thousand for the decade. Estimate (a) suggests that in the absence of decrease in mortality the birth rate would go up to 39.36 per thousand. This phenomena can be explained easily if it is recognised that the mortality gains were mainly in the younger and older age groups. Thus constant mortality implies a smaller denominator in the calculation of rates. And with fertility remaining constant the numerator may not be altered much. Estimate (b) shows

that a slight decline in the birth rate is associated with the declining mortality. If a steady decline in mortality and fertility were operating during the decade the birth rate would be about 37.5.

It was not possible to estimate infant mortality rates directly. But child mortality (children dying before attaining the age of 5 years among the total born) shows almost identical figures for estimates (b), (c) and (d). Mortality appears to be the chief determinant of this rate. The changes due to decline in fertility appear to be negligible.

The expectation of life at birth, obtained from the life tables derived using the survival ratios used for the calculation of the various estimates, is found to be 50 years for males and 55.5 years for females. These figures are much less than the figures obtained by the Kerala State Planning Board, viz., 56 years for males and 60 years for females[15]. The values obtained in this study are in agreement with the general findings of the United Nations on the gains in the expectations of life in developing countries[16].

It must be pointed out here that the rates shown here are the direct products of the assumptions on which the estimates were made and should not be taken as indices based on data. The purpose of presenting the rates was mainly to indicate the influence changes in mortality and fertility has on vital rates. Also the reasonableness of the estimated rates enhances the reliability of other findings.

Age Structure

Whether a declining mortality tends to make a population younger or older depends upon the age at which the decline is greater. If there are considerable gains at the younger ages as compared to those at older ages, the declining mortality has the same effect as that of increasing or constant fertility. It is of interest to examine the changes that can occur in the age structure of Kerala population for the different assumptions on mortality and fertility.

Figures of Table 4 show that the median age of the population would decrease from what was 19.33 years in 1961 to 18.91 in 1971 (see estimate (b)) if the decline in mortality noticed during 1951-1961

continues at the same pace during the 1960's. The population has become younger mainly because of the gains in mortality that was greater at the younger ages. In the absence of a decline in fertility the number of survivors at the younger age groups would have increased so as to lower the median age. It can be noticed that with a decline in fertility, the median age increases. However even under an optimistic assumption (estimate (d)) the median age does not reach the 1961 value. In other words the fertility decline assumed here is uot adequate enough to compensate the decline in mortality. Thus, if the population has to make greater economic progress greater decline in fertility is essential.

Table 4

AGE STRUCTURE AND DEPENDENCY RATIO, 1971 CALCULATED UNDER THE FOUR ASSUMPTIONS AND THE 1961 VALUES

		Estimates			
	1961	(a)	(b)	(c)	(d)
Median Age	19.33	19.31	18.91	19.01	19.20
Proportion under 15 yrs. (%)	42.64	40.29	41.23	41.05	40.57
Proportion between 15 & 64 yrs. (%)	53.76	56.49	55.59	55.84	56.29
Proportion between 20 & 55 yrs. (%)	40.43	40.83	40.18	40.36	40.69
Proportion over 65 yrs. (%)	3.60	3.22	3.09	3-11	3.14
Proportion over 55 yrs. (%)	8.45	7.62	7.41	7.45	7.51
Dependency Ratio $\frac{(<15)+(65+)}{(15-64)} \times 100$	86.01	77.02	79.89	79.08	77.65
Dependency Ratio $\frac{(<20)+(55+)}{(20-54)} \times 100$	147.34	144.92	148.88	147.77	145.76

The median age is directly influenced by the porportion of persons in the younger age groups. The proportion of persons under 15 years for Kerala is typical of a population of a developing country that has a high birth rate and a declining mortality rate.

The influence of declining mortality appears to be to increase the proportion under 15 years and that of declining fertility to decrease the proportion. The estimates show that even a steady decline both in mortality and fertility need not yield a figure equal to what would have been the case if there had been no decline in mortality and fertility since 1961. Once again it is a reminder that only a substantial decline in fertility can compensate for the small gains achieved through death control.

The decline in mortality has resulted in an increase in the number of persons in the age groups beyond 65 years though not in terms of proportions. Declining mortality has made the population younger and the decline in fertility as assumed here has not helped to stop the tendency. In 1971, the Kerala population is likely to be younger than in 1961. It can be concluded that with large numbers of persons at the extreme age groups, the dependency burden on the economically productive group may increase.

On an anlysis of the dependency ratios calculated using the conventional definition of the ratio of the number of persons under 15 years and above 65 years to those between 15 and 65 years, shows that the value of the ratio is bound to come down considerably by 1971. However, if instead of 15 to 65 years, 20 to 55 years is chosen as the age limits of the productive population of Kerala, whis is more relevant as far as Kerala is concerned, the reduction in the dependency burden is not considerable during the decade. This difference in the values due to the different definitions is due to the fact that mortality gains have been greater in the age groups beyond 60 years than in the age groups 25 to 60. Realisation of the fact that a decline in mortality and a very slow decline in fertility, if at all there is any, would increase the number of persons entering the labour force, suggests that the small gains in the dependency would be offset by unemployment problems if adequate economic opportunities are not created sufficiently earlier.

Conclusion

The population of Kerala for 1971 has been estimated on the basis of some reasonable assumptions regarding mortality and fertility. The results show that if the population had grown under the condition of constant mortality and fertility as prevailed in 1961, the advantages in terms of age structure and growth would have been the maximum. However an assumption of constant mortality is unrealistic. Steady decline in mortality with fertility showing signs of decline after 1966 appears to be fairly reasonable. If population growth was under such a set up, the Kerala population would be economically at a disadvantageous position as compared to 1961. Even a steady decline in fertility accompanying the declining mortality, as assumed here does not show that Kerala is poised for a demographic transition. The gains in mortality have been mainly in the younger and older age groups and consequently even small advantages accruing out of a steady decline in fertility is bound to be offset by the demands of a larger number of younger persons entering the labour force.

The next decade, 1971-1981, may see further decline in mortality and fertility. As mortality decline is bound to be slow hereafter and as fertility may decline at a greater pace due to the impact of family planning programmes, the population is bound to have a larger number of youths entering the labour force. This, coupled with the rate of growth of population slowing down will set a stage very suitable for economic prosperity.

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[13] United Nations, *Methods of Estimating Basic Demographic Measures from Incomplete Data,* Manual IV. United Nations, 1967.

[14] Namboothiri, N.K., Op cit. Note 2.

[15] State Planning Board, Kerala Government. Op cit.

[16] United Nations., Model life Tables. Note 9.

Mortality in India in Relation to Prospects of Fertility Decline*

S. Krishnaswamy Rao, P. S. Mohapatra and P. S. Bhatia

Introduction

Owing to their preoccupation with fertility measurements and family planning during the past decade demographers in India have not been able to pay enough attention to the study of mortality, an area almost as important as fertility for the family planning programme. This paper seeks to examine the prospects of fertility decline vis-a-vis decline in mortality, and to highlight the trends and some of the causes of recent mortality decline in India with the help of available data.

While studies in India have shown that three to four children are generally desired by a large fraction of the population, it appears paradoxical that little use of family planning information and services would be made by them even when these are made available to them. It may be that organizational arrangements for supplying the means of fertility control are either inadequate or traditional cultural values are inconsistent with adoption of family planning in early parenthood. This explanation has not been supported by any study so far. Another explanation is that the predominant social norm of having three-four children per couple is not inconsistent with a much higher number of live births, say six-seven in view of the continuing high mortality in India, especially in ages 0-5 years. Evidence is already available to support the hypothesis that favourable attitudes and practice of family planning are more common within given strata of the society if number of living children is four or more. Considering such evidence, Freedman has argued that "Availability of means for fertility control may be irrelevant until what is regarded as essential minimum number of children is achieved"[1].

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With rare exceptions, mortality decline in the Western European countries and other industrially developed societies has always preceded decline in fertility. It has also been hypothesized that rising standards of living and better nutrition was associated with both mortality and fertility decline in the West. It is, however, difficult to isolate the individual contributions of improvements in mortality conditions and of improvements in socio-economic conditions towards decline in fertility, and to determine the extent to which these factors are preconditions for fertility decline. It has also been theorised that a substantial decline from a high level of fertility can occur only after a critical level in several demographic and socio-economic factors is reached. We shall examine in this paper the extent to which Indian conditions in these respects differ from those in other developing countries which have recently recorded a sharp decline in fertility levels.

Gains in Mortality in India

In the absence of accurate vital statistics for India, census actuaries have estimated vital rates by indirect methods. Table 1 provides a picture of the changes in mortality and fertility conditions in the country during the present century. Even though the absolute values of crude death rates and especially infant mortality rates may have been underestimated, the trends of declining mortality in the country emerge clearly[2].

Table 1

VITAL RATES FOR INDIA, 1901-71

Period	Death Rate	Infant Mortality Rate+	Birth Rate
1901-11	42.6	222	48.1
1911-21	48.6	212	49.2
1921-31	36.3	176	46.4
1931-41	31.2	168	45.2
1941-51	27.4	148	39.9
1951-61	22.2	106	41.7
1961-65	17.2*	80	41.0*
1966-71	14.0*		38.5++

Source : Growth of Population in India, Ministry of Health, Government of India 1962, New Delhi.

* Assumed by Expert Committee on Population Projections appointed by the Government of India

\+ Registration Data – Office of the Registrar General, India

++ Estimated by authors

The fourteenth, fifteenth and seventeenth rounds of the National Sample Survey have yielded estimates of rural death rates of 19, 15 and 12 per 1000 persons for 1958-59, 1959-60 and 1961-62, respectively[3]. The mortality trends have been graphically presented in Figure 1. The consistency in mortality decline began

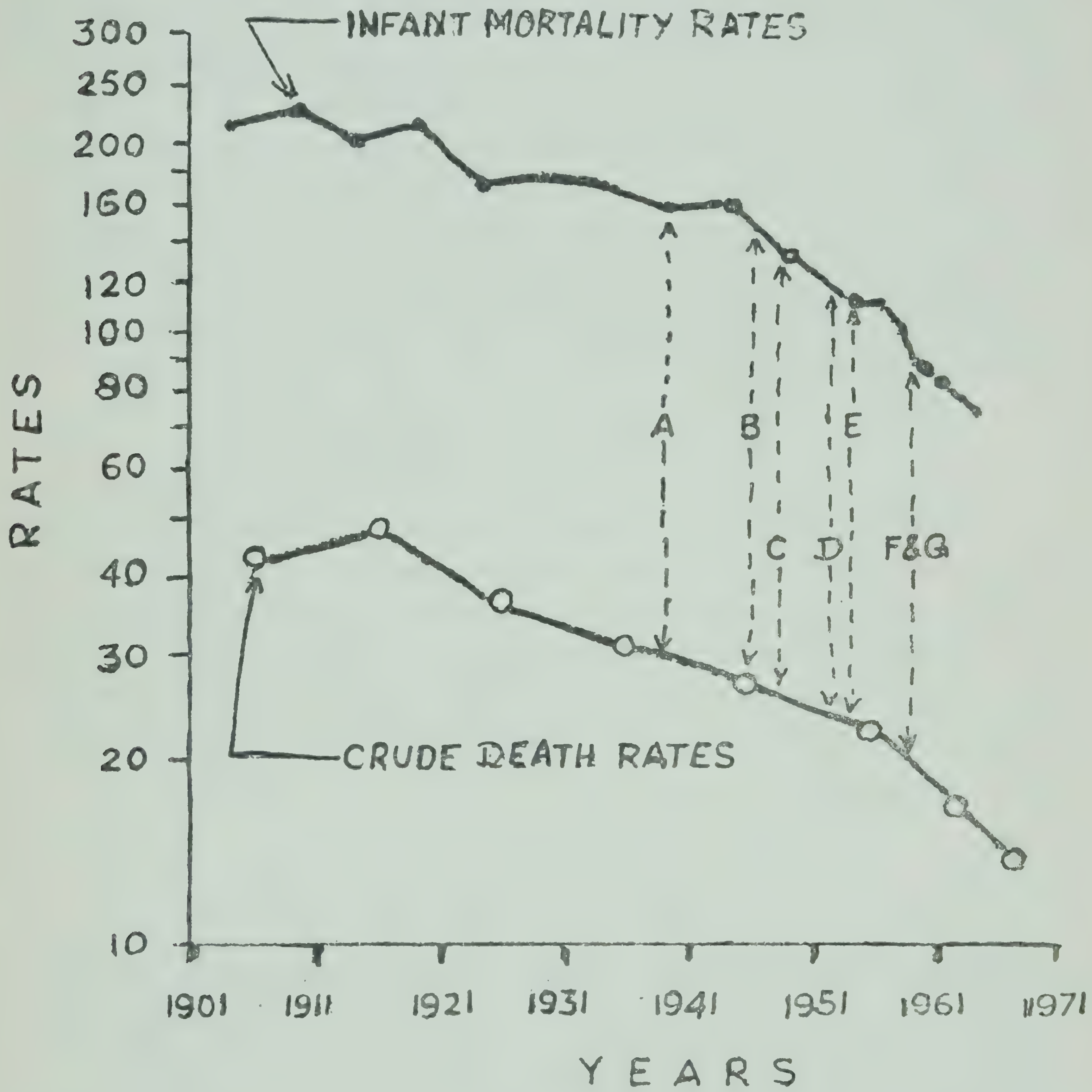


Fig. 1: *Trends in infant mortality rates & crude death rates in India.*

A — Chemo Therapeutic Drugs, B — DDT, C — Antibiotics,

D — Malaria Control Programme, E — Polio Vaccine

F — Identification of Endemic Cholera Centres

G — Achievement in 50% of the Target Number of P. H. Cs.

only from the decade 1921-1931 when the inter-censual death rate centred around 1926 was estimated to be 36.3 per thousand population. Then followed a period of slow decline of mortality for the next 20 years by the end of which (i.e. during 1941 - 1951, centred around 1946) the death rate came down by 24. 5 per cent to a level of 27.4. A relatively higher rate of decline (38.0 per cent) was observed during the next 20 years, if we assume the death rate during 1966 to be about 17.

The gain in mortality during the last 40 or 45 years is reflected in the differential gains in specific age groups, particularly the younger ones. This is illustrated in Table 2, giving life table mortality rates for India for 1941-1951 and also the per cent decline in different age groups during these ten years, for males and females separately.

Table 2

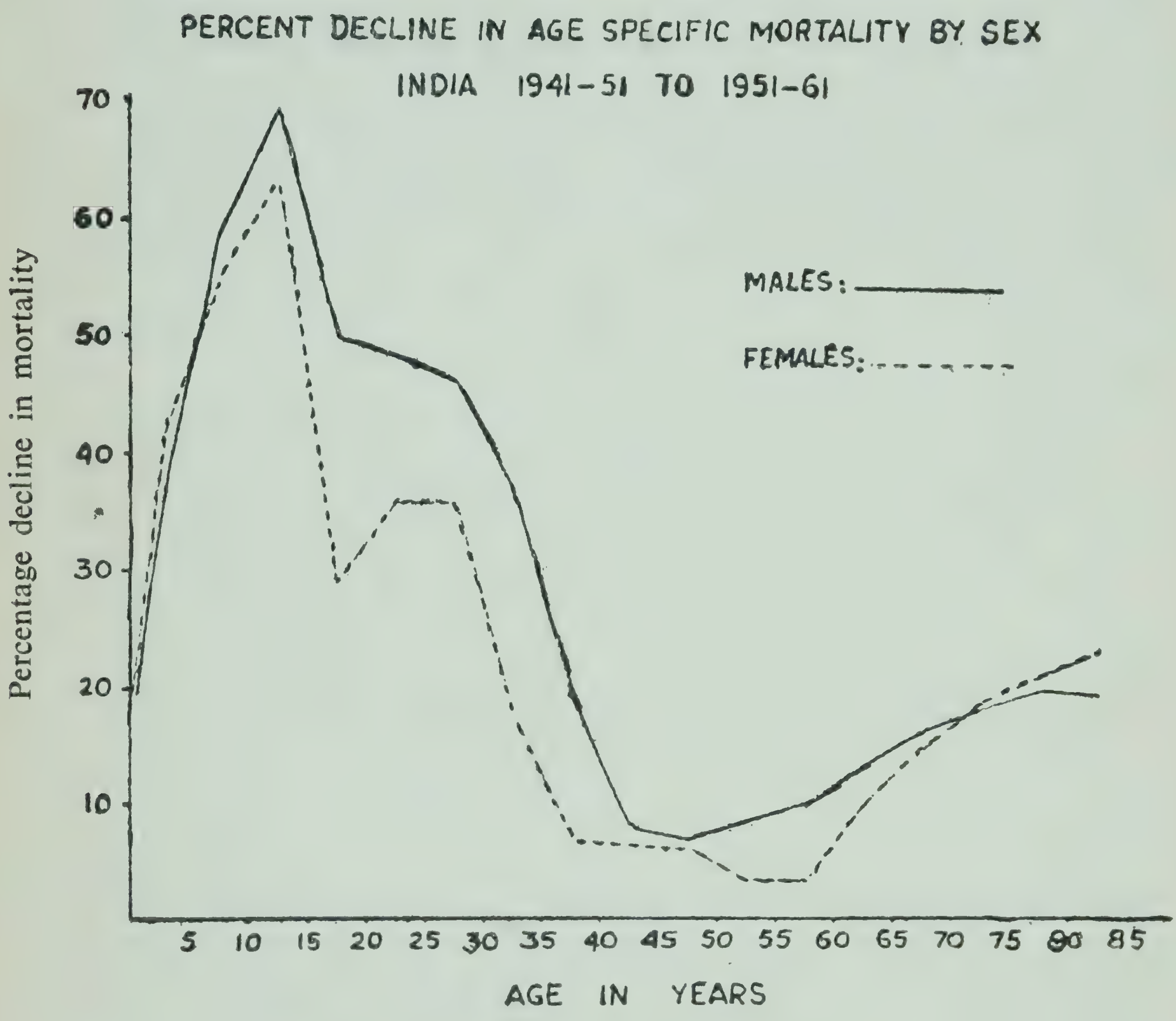
AGE SPECIFIC DEATH RATES BY SEX FOR 1941–51 AND 1951–61 FROM INDIAN LIFE TABLES

Age group	Male		Percentage Decline	Female		Percentage Decline
	1941–1951	1951–1961		1941–1951	1951–1961	
0–1	190.00	153.22	19.4	175.00	138.26	21.0
1–4	135.21	83.53	38.2	174.85	100.23	42.7
5–9	74.62	30.91	58.5	84.01	37.88	54.9
10–14	58.35	17.92	69.3	53.61	19.69	63.3
15–19	50.46	25.33	49.8	37.79	26.86	28.9
20–24	54.19	27.99	48.3	44.29	28.37	35.9
25–29	62.15	33.50	46.1	65.77	42.13	35.9
30–34	73.93	46.90	36.6	90.28	74.21	17.8
35–39	88.13	71.19	19.2	107.80	100.16	7.0
40–44	104.32	96.18	7.8	120.20	113.16	6.4
45–49	130.54	121.70	6.8	136.23	127.60	6.3
50–54	168.36	154.11	8.5	156.91	151.39	3.5
55–59	217.59	195.84	9.9	191.01	184.78	3.3
60–64	284.97	246.75	13.4	251.22	226.15	10.0
65–69	367.96	307.58	16.4	321.78	273.69	14.9
70–74	466.00	379.57	18.5	405.99	329.00	19.0
75–79	576.00	461.91	19.8	503.03	391.99	22.1
80–84	690.80	556.94	19.4	609.08	467.96	23.2

Source : Registrar General, India, Life Tables of 1941–51 and 1951–61

It is observed (Figure 2) that while the per cent mortality decline in ages 0-1 during these ten years was of the same order as that for crude death rate (around 20 per cent), gains in other younger ages were of a much higher order.

Fig. 2:



It is clear that for both males and females a reduction in mortality of more than 25 per cent has been achieved in the ages 1-30 during the period under consideration. In some age groups the reduction was as much as 69 per cent. The significance of such differential gain in the young ages is that proportionately larger percentages of the population have entered child bearing ages from the latter cohort as compared to the earlier cohort, which is likely to result in a corresponding increase in the number of births.

Causes of Mortality Decline in India

Generally, the transition from high to low mortality in Western countries has been attributed to improvements in agriculture, communication, environmental sanitation and water supply, better medical facilities, control of epidemics and so on. By and large, mortality decline in the Western countries has been rather gradual, spread over the latter part of eighteenth century and most of the nineteenth century. In England and Wales it took more than a century and a half for the death rate to reduce from a level of 33 per thousand in 1741 - 1750 to a level of 18.2 in 1891 - 1900[4]. This happened long before the important life saving advances in medical sciences had become available. Correspondingly, in India the death rate declined from 36 during 1921-1931 to approximately 16 or 17 during 1961-1971—a period of 40 years. This has been possible not so much due to improvements in level of living or changes from a traditional way of life to a modern way of life as due to control of famines, control of mass killers such as malaria, cholera and smallpox and introduction of life saving drugs in the country. Specifically, the downward trend in mortality and a fast decline in infant mortality during the last 20 years have been associated with certain events which may be chronologically shown as below:

EVENTS	YEAR
1. Introduction of Chemo-therapeutic drugs such as Sulfas	1939
2. Availability of DDT for use by the civilian population	1946
3. Introduction of Antibiotics	1947
4. Beginning of mass malaria control programme	1952-53
5. Introduction of polio vaccine	1954
6. Identification and isolation of endemic cholera centres	1959
7. Achievement of 50 per cent of the target number of Primary Health Centres in the country	1959

Corresponding improvements in social and economic conditions in the country over the same period have not been significant. The literacy rate in India in as late as 1961 was only 24 per cent. Index of per capita food production in 1966-1968 (as compared to 100 in 1952-1956) was 97. There have, however, been

some outstanding gains in food production since 1968. It is true that part of the mortality decline during the 1920s, and 1940s has been due to control of famines through better communication and wider distribution of food. It is equally true that while the present control of famines has prevented many deaths caused by starvation, the level of nutrition has not improved enough to prevent a high level of morbidity. It may, therefore, be argued that the decline in mortality has not been as much due to improvements in environmental sanitation, nutrition and a significant increase in level of living as due to imported technology for prevention of deaths.

Fertility Trends in India

Since it is not our intention to have a detailed discussion on fertility in this paper we shall present some data which would be indicative of fertility trends rather than of levels. For this purpose, crude birth rates derived through analytical methods from census data for the decades of the current century have been presented in the last column of Table 1.

The only inference that can be drawn from the above data are that birth rates were at a level of 45 or above till 1940. Even the subsequent fall in birth rate cannot be attributed to a real decline in fertility level. Firstly, there was little evidence of significant change in the social structure which could lead to fertility decline, nor were birth control methods used by a substantial proportion of the population. Secondly, the basis of estimation of birth rates during the different decades was different. There was not substantial drop in fertility rate upto 1965, as is evidenced from the percentage distribution of population during the five census years 1911-1951 in the broad age groups 0-14, 15-49 and 50 years and above. The distribution remained virtually constant during this period. The slight increase in the percentage of population aged 0-14 years observed in 1961 may have been due to one or more of the reasons given below:

a. Sharp decline in infant mortality rate.

b. Slight increase in the birth rate caused by reduction of female mortality and widowhood in child-bearing ages.

The Expert Committee on Population Projections, in its medium projections for the future growth of population of India has assumed a birth rate of 41. 0 during 1966[5]. Using this as the base, and applying analytical techniques to family planning statistics, various experts have placed the 1969 birth rate as between 38 & 39, a drop of 2 to 3 points from the 1966 level. If this happens to be the beginning of a continuous and long term trend of fertility decline, it may be said that such decline has probably started in 1966 the year in which family planning efforts began on a massive scale.

An International Comparison of Fertility and Mortality Trends

The relevance of the foregoing discussions on the Indian experience in fertility and mortality is seen when we compare this experience with those of other developing nations now on their way to achieving a low fertility level. Here it may be mentioned that often the performance of India in family planning and; in fertility reduction is compared with those in Taiwan, Hongkong, Singapore and Korea where significant reduction in fertility has occurred during the last decade. This comparison appears somewhat unfair for several reasons. Firstly, India is a much larger country with diverse population with respect to religion, language, ethnic origin and social and cultural norms. Secondly, mortality in these other countries had already reached a very low level when their birth rates started declining. Finally, although these countries are generally grouped as "developing countries" the levels of development in various social and economic areas in these countries during the last decade has been much higher than those in India.

To illustrate the association of fertility decline with mortality decline we have chosen two of these countries, Taiwan and Singapore, for whom reasonably complete data for crude birth and death rates and infant mortality rates are available from 1921 onwards. These rates have been presented in Table 3 and figures 3 and 4 along with comparative data from India.

Table 3

CRUDE BIRTH RATES, DEATH RATES AND INFANT DEATH RATES FOR SELECTED ASIAN COUNTRIES

Year	Birth Rate		Death Rate		Infant Mortality Rate*	
	Taiwan*	Singa-pore*	Tiwan@	Singa-pore@	Taiwan	Singa-pore
1920–24	41.8	28.9	25.8	30.5	—	222.9
1925–29	44.0	33.2	22.8	29.0	—	212.4
1930–34	45.5	38.5	20.6	23.8	152.8	181.3
1935–39	44.7	46.0	20.2	22.1	144.4	152.4
1940–44	41.7	44.9	18.2	20.8	127.5	219.0
1945–49	40.2	46.4	15.1	12.5	59.6	98.7
1950–54	45.9	45.5	10.0	10.4	33.6	67.1
1955–59	42.8	42.8	8.0	7.3	34.3	42.5
1960	39.5	38.7	6.9	6.3	30.5	34.8
1961	38.3	36.5	6.7	6.0	30.7	32.1
1962	37.4	35.1	6.4	5.9	29.1	31.0
1963	36.3	34.7	6.1	5.8	26.4	27.9
1964	34.5	33.2	5.7	5.8	23.9	29.3
1965	32.7	33.1	5.5	5.6	22.2	26.1
1966	32.4	29.8	5.4	5.5	20.2	24.6
1967	28.5	27.1	5.5	5.4	20.6	24.8
1968	29.3	24.8	5.5	5.6	19.0	23.4
1969	25.6	22.2	5.3	5.1	—	20.8

Source : United Nations, Demographic Yearbook.

It is observed that:

a. Birth rates in Taiwan and Singapore were more or less constant and at a level of around 45 until 1952-1953 by which time the death rates in these countries had reached a level of 10 per thousand. In contrast, in India, the death rate even now is at a level of above 15 per thousand.

b. The sharp decline in fertility in Taiwan and Singapore began only after 1956 by which time the death rate had fallen below 8 per thousand.

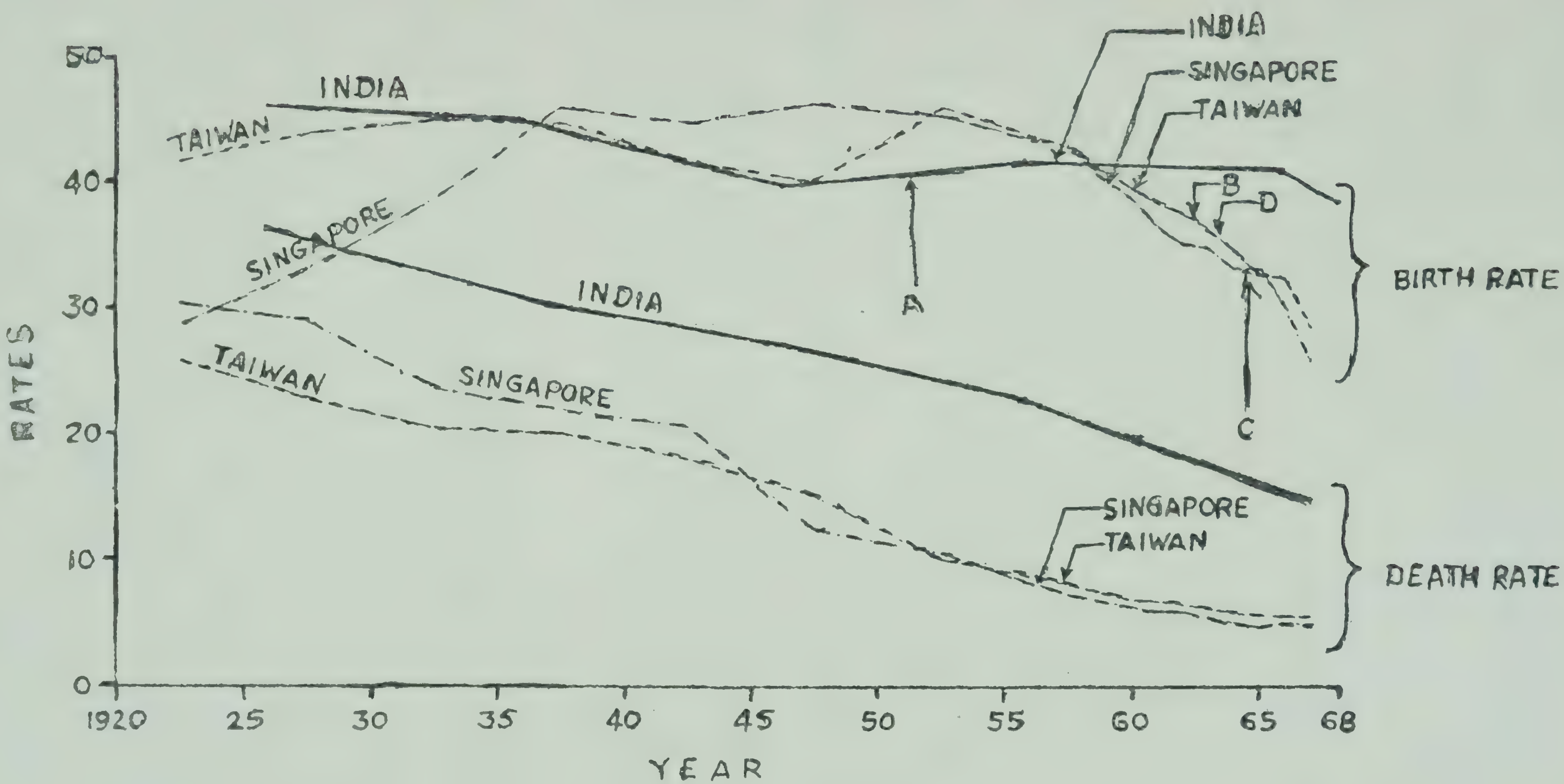


Fig. 3 *Trends in crude birth & death rates, India, Taiwan & Singapore*

A, B & C: Family planning programme began in Indian, Taiwan & Singapore

D: Extension approach adopted in India

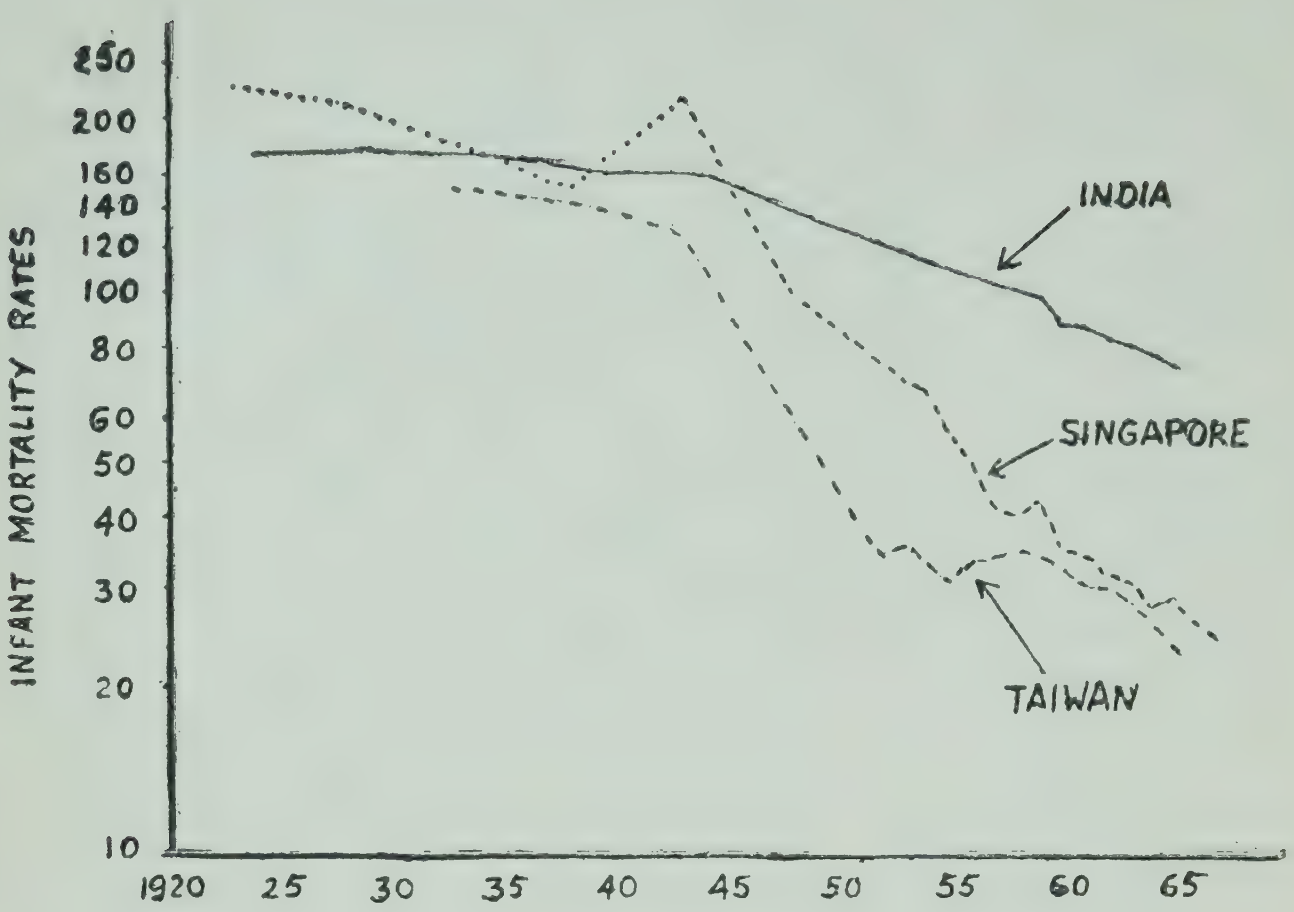


Fig. 4 *Trend in infant mortality rates in India, Taiwan & Singapore*

c. The trend lines in death rates in all the three countries are almost parallel to each other, with India approximately 25-30 years behind the other two countries in registering a corresponding level of mortality.

d. The present level of infant mortality in India of around 120 was achieved in Taiwan and Singapore by 1946 almost 25 years back.

e. By the time birth rate began to fall in Taiwan, the infant mortality rate in that country had reached a level between 30 and 35 per thousand live births and has been below 30 consistently since 1960. In the case of Singapore infant mortality rate was below 60 when the birth rate began to fall around 1952 and has been below 35 since 1958. For both these countries the infant mortality rate had reached a level of 25 or less by 1967. Correspondingly, in India, the registered infant mortality rate for the period 1951-1956 and 1956-1961 were 113 and 98 respectively, which are known to be grossly underestimated.

It is obvious that although mortality in India has had an accelerated decline during the recent years it has still not reached the level which Taiwan and Singapore achieved in the early 1950s when a spontaneous birth rate decline in these countries began, Considering that the population structure in these countries are more or less similar to India's in so far as all of them have an extreme young population, it may be fairly assumed that a similar long term and consistent fertility decline in India can only begin after the Indian mortality goes down further.

Relationship between decline in mortality and fertility is a complex mechanism and cannot be studied in isolation from social and economic conditions existing in a country which have a significant bearing on family size norms and attitudes towards family planning practice. A comparison of India with Korea, Hongkong, Singapore and Taiwan with respect to some of the indicators of these socio-economic aspects clearly show that India is still behind the other countries. This can be seen from Table 4 which provides some comparisons among these countries, in terms of per capita income, index of the per capita food production, per cent literates, index of school enrolment ratio, newspaper circulation and radio ownership per thousand population, population served per doctor, nurse, midwife and hospital bed, and per capita consumption of energy and food calories.

It may be relevant to note here the years in which the official family planning programme began in some of these countries and the existing fertility levels and trends at that time. Although the Indian programme officially started as early as 1952, the first 10 years of the programme were mostly exploratory and experimental. This was inevitable because as a pioneering country, India had to step cautiously in the matter of family planning policy during the early years of the programme. The family planning policy underwent a major shift in 1963 when the extension approach was adopted for the programme. It, however, took almost three years to implement the new approach to a reasonable extent and 1966-1967 was probably when the efforts began to bear fruit. It may be noted that up to this point of time there was hardly any discernible decline in fertility in India. Even at the present moment, the family

Table 4

INDICES OF DEMOGRAPHIC, SOCIAL AND ECONOMIC DEVELOPMENT IN SELECTED ASIAN COUNTRIES

	Demographic	India	Hongkong	Singapore	Taiwan	Korea
1.	Population Density per sq. km. (1967) @@	156	3,770	3,367	360	302
2.	Per cent living in :					
	a. Urban areas (1967)@@	18	73	100	–	30
	b. Cities with 100,000 population	8	–	100	32	23
3.	a. Crude Birth Rate (1969)@@	39	23	26	28	32–34
	b. Crude Death Rate(1969)@@	16	5	5	6	9–11
4.	Percentage of married female (15–44) (1969) @@					
	a. Out of total population 1969	17.9	12.5	14.5	12.3	14.4
	b. Out of all females 15–44 1969	84.2	62.5	72.5	60.7	67.2
·	Social and Economic					
5.	Per capita income (1966)@	79	298	529	199	117
6.	Index of per capital food production in 1966–1968 as compared to 1952–1956=100@@	97	(63) –	–	110	124
7.	Per cent literates (Ages 15+(1960–1961)**	28 (61)	71	50 (57)	54 (56)	71
8.	Daily newspaper circulation per thousand population (1965–1966)@	13	349	268	64 (63)	51
9.	Radio sets per thousand population 1966@	13	159	214 (64)	106	63
10.	Adjusted school enrolment ratio (1965)@@	44	80	85	77	72
11.	Average population served per (1968)@@					
	Doctor	4,800	2,300	1,800	2,300	2,500
	Midwife	9,700	–	1,100	5,100	5,000
	Nurse	9,600	1,100	600	7,700	3,200
	Hospital bed	1,700	300	300	1,000	1,300
12.	Estimated calories food supply (1961–1962)*	2,020	–	–	2,350	–
13.	Energy consumption in coal equivalent kg. per capita (1966)@	171	655	824 (63)	706	510

@ United Nations - Demographic Year Book, 1967

@@ Population Council Report on Population/Family Planning (December 1969)

* United Nations Current Economic Development. World Economic Survey 1964–Part II, New York, 1965.

** United Nations Statistical Year Book, 1964.

planning programme is perhaps counteracting the increasing trend in fertility due to reduction of female mortality in child-bearing ages.

The official family planning programme in Taiwan began in 1963 and in Singapore in1965. Table 3 indicates that a consistent decline in fertility in these two countries had begun at least ten years before this date. By the time of official adoption of family planning in Taiwan, the birth rate had gone down to 36.3 and in case of Singapore it had been down to 33.1, while roughly 10-12 years earlier the birth rates were around 46 in both these countries. In other words, the individual motivations required for lowering family size which were most likely influenced by low mortality and a reasonable level of social and economic development were already existing in these two countries when the programme started. This was obviously not ture in the case of india.

In India, some States have progressed much farther than others in terms of improvement of mortality conditions and certain indicators of modernization and urbanization, although they may not have reached the levels achieved by the countries discussed above. Taking a lead from the above discussions it may be possible to offer some hypotheses regarding prospects of fertility decline in some of these States.

An example may be drawn from Kerala. Figures 5 and 6 show that although Kerala is far ahead of the country as a whole in terms of improvements in general and infant mortality, and has a much higher population density, literacy rate, newspaper circulation rate and proportion of institutional births, its birth rate is only marginally lower than that for all-India despite a relatively lower proportion of married females. This could be because the 'critical' level required for a spontaneous fertility decline has perhaps not yet been reached in Kerala. The mortality trends in Kerala suggest that they may reach the levels achieved by Taiwan and Singapore in the 1950s during the early part of the current decade. It may then be hypothesized that Kerala will register a sharper fertility decline than the country as a whole within the next ten years.

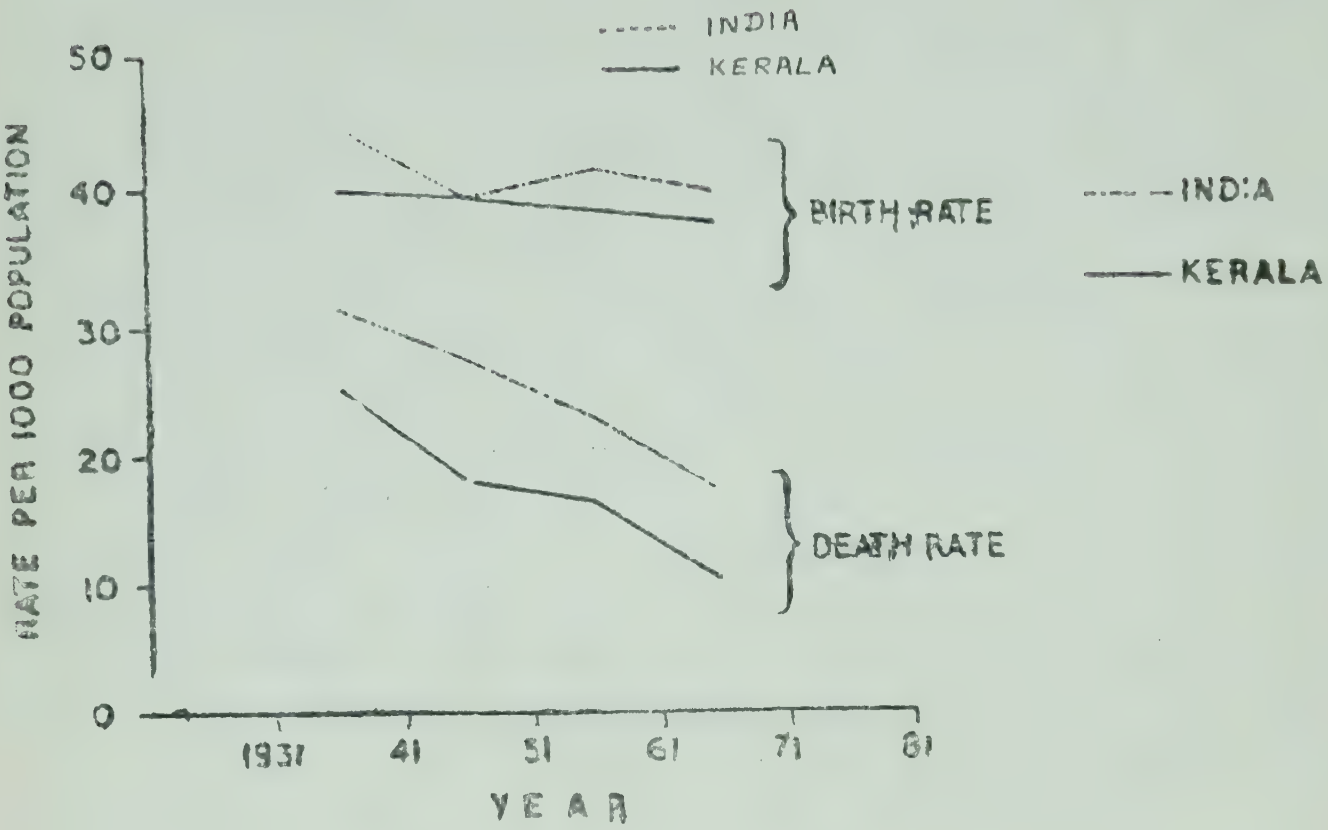


Fig. 5 *Trend in Birth and Death Rates in Kerala and India Since 1931*

CONCLUSIONS

A viable family planning programme can accelerate an already existing trend of fertility decline as is perhaps true in the cases of Taiwan, Korea, Hongkong and Singapore. When such a trend starts on its own, it points to certain favourable societal conditions, such as low mortality levels and preparedness on the part of the population for acceptance of family planning through individual motivation. In the case of India, it is easy to see that the programme has been fighting an uphill battle against many obstacles, not the least of which is the existing levels of general and infant mortality which are fairly high. It may further be argued that in this country the institutional, social, demographic and economic conditions have perhaps not yet reached the 'critical level' which would touch off widespread acceptance of family planning. Under these conditions and considering that the major thrust in India's family planning programme came as late as 1965 or 1966, it is probably premature to expect a substantial decline in birth rates in such a short time. Some

SELECTED DEMOGRAPHIC AND SOCIAL CHARACTERISTICS OF KERALA AND INDIA

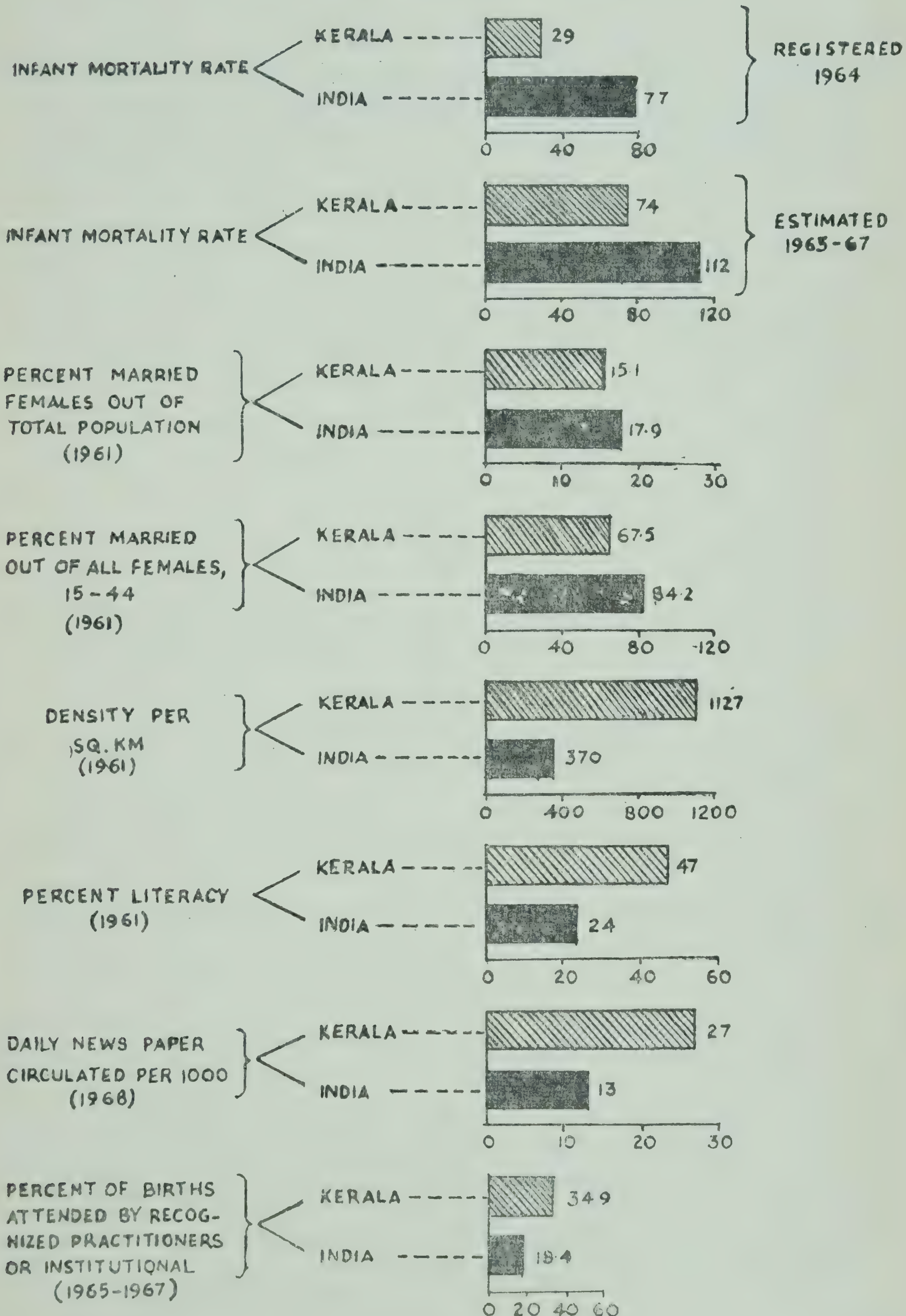


Fig. 6

states (example, Kerala) which have already achieved low levels of mortality may be expected to register a sharper fertility decline than the country as a whole.

The above discussions are not intended to mean that the family planning programme in Inda will be ineffective until the 'critical' levels in the related factors are reached, but only to point out the high odds against it, the sources of which are to be tackled simultaneously with the family planning programme. As one of the preconditions for achieving a fertility decline is low mortality, it may be suggested that deliberate attempts at improving infant and child mortality through effective maternal and child care is likely to accelerate the realization of the objectives of the family planning programme.

NOTE

1 Freedman, R., "The Sociology of Human Fertility, A Trend Report and Bibliography", *Current Sociology* Volume XXI, No. 2, 1961, pp. 48.

2 *Growth of Population in India,* Ministry of Health, New Delhi, 1962.

3 Reports of the National Sample Survey for fourteenth, fifteenth and seventeenth rounds.

4 *World Population and Resources* : *A rport by PEP,* George Allen and Unwin Ltd., London 1964.

5 Reports of the Expert Committee on Population Projections, Government of India, New Delhi, 1969.

Effect of Declining Mortality on Fertility: A Study with a Deterministic Model

R. S. S. Sarma

Introduction

Information on length of marriage is useful for economic and social planning. The proportion of marriages remaining unbroken throughout the reproductive life has a direct bearing on the fertility of any community. In a study done in India, it was found that the death of husband before the end of wife's reproductive age reduced the average size of family by about one child[1]. In the same study, a greater prevalence of widowhood and earlier widowhood were supposed to have been responsible for the difference in the average number of children born to women in rural as compared to urban areas.

As a consequence of the decline in mortality, couples marrying today can look forward to a longer life time together, than those who married years past. In the United States, in fact it did result in a greater proportion of marriages unbroken by death of either partner. In the beginning of this century, marriages were broken by the death of either spouse at a rate of about 28 per 1000 a year and the reduction in mortality since then had brought this rate down to about 18 per 1000 by about 1950[2].

In this paper an attempt is made, by means of a deterministic model, to study the effect of decline in the general mortality, on the average length of married life, and the level of fertility. It is also attempted to study the effect of changing age at marriage of wife on level of fertility under varying conditions of mortality.

The present model is programmed and the computations are done on a time-sharing computer.

The Model

Assumptions :

The present model assumes that (i) all women marry exactly at a particular age, e.g., 15 years; (ii) husbands are older than the wives by exactly 5 years; (iii) divorces and remarriages of widows are nil; and (iv) reproduction takes place between 15 and 45 years of age of wife.

Methodology

The methodology adopted and the computational details of the study are as follows:

1. *Average Number of Anticipated Reproductive Years* : Denoting the probability that wife aged X will survive to age X+1 by P_x^W and the probability that her husband will survive for the same period by P_x^H, we have the probability that the marriage will remain unbroken from age X to X+1 of wife as simply $P_x^W \cdot P_x^H$. These probabilities of joint survival are applied to a cohort of 100,000 women married exactly at age 15 in order to obtain the number of women in currently married state at each of the ages 16, 17, etc.

The number of currently married women aged exactly X years are denoted by W_x. The number of currently married women in any age group X to X+1 are worked out as equal to $(W_x + W_{x+1}) / 2$ denoted by ${}_1W_x$. The number of women-years of currently married life remaining before the end of reproductive life, is denoted, for a wife aged X, by T_x and is given by $\sum_{t=x}^{44} {}_1W_t$. Finally, the average number of reproductive years within marriage for a wife aged X, are computed as $A_x = T_x/W_x$.

Since the Life Tables used here, give the numbers of persons at exact ages X, X+5 etc., linear interpolation is adopted to obtain the numbers at exact ages X, X+1, etc.

Computations are also made with the age at marriage of wife fixed at 16, 17, 18, and 19 years, separately.

2. *Level of Nuptial Fertility Rate*: The number of currently married women aged X to X+1 is given by ${}_1W_x$ for different levels of mortality. A fixed schedule of annual nuptial fertility rates is applied to the age structure of the currently married women, obtained above, in order to compute the number of live births in a year. The nuptial fertility rate is the ratio of annual number of live births per 1000 currently married women. The nuptial fertility rate so obtained, reflects only the change in the age structure and does not take into account the change in the proportion currently married. By multiplying the unadjusted nuptial fertility rate by the corresponding proportion currently married, the adjusted nuptial fertility rate is obtained.

3. *Comment on the Two Indices Proposed*: The effect of declining mortality on fertility is, in this paper, measured by two indices: (i) Average number of years of married life within reproductive ages, and (ii) Annual number of live births per 1000 currently married women.

Had detailed data been available, it would have been possible to consider how much increase in fertility, in terms of number of children ever-born, could be expected by this increased length of married life. Fertility of a woman is known to be function of her length of married life. But the exact functional relationship, even under non-contraceptive conditions, is difficult to assume. The nature of relationship can at best be analysed with the help of information on spacing between live births. Spacing between live births is not constant throughout the reproductive life of a woman. Spacing is believed to increase towards the end of the reproductive life. In addition to the increased spacing, the secondary sterility increases. Increased spacing and increased extent of secondary sterility will contribute to a smaller rate of reproduction towards the end of reproductive life. In view of these considerations, it may not be valid to assume constant spacing throughout the reproductive life span and thus not possible to express the number of years of effective marriage in terms of number of live births unless detailed information on spacing in different phases of reproductive

life span is available. However, the foregoing discussion leads us to expect that, due to the declining mortality, there cannot be as much change in the level of fertility, in terms of number of live births, as there is in the number of years of married life. This fact is demonstrated by the second index, namely, annual number of live births per 1000 currently married women.

In order that the effect of decline in mortality be correctly reflected in the level of fertility indicated by the second index, the nuptial fertility schedule used should be constant and preferably of a non-contracepting community.

Data Used

A set of 24 Model Life Tables were prepared by the United Nations[3] with expectation of life at birth ranging from 20 to 73.9 with an increment of about 2.5 years from one life table to the other. Coale and Demeny[4] also had published four different sets of 24 life tables each, corresponding to the four regions, West, North, East, and South.

The life tables in each set are considered as the transitional populations in the present study. As the method of construction of Model Life Tables due to Coale and Demeny is claimed to be better than that of the United Nations, a major part of the computations are carried out only on the U.N. tables, but also on these four sets and the results are tabulated seperately for the four regions.

The range of expectation of life at birth considered in this paper is from 30 to about 70 years.

The constant fertility schedule used in this study is from a study on the fertility of a rural community in India, and contraception in that community was known to be practically absent[5].

The Findings

Proportion of Women in currently married state:

As a result of declining mortality, characterised by the increase in expectation of life at birth, greater proportions of women remain in currently married state. It can be seen from Table 1,

that in the case of U.N. life tables, currently married women form about 80 per cent of all women in reproductive ages when $e_0^0 = 30$ years, and this percentage increases to over 97 when e_0^0 reaches about 70 years. In the case of Coale-Demeny tables, the percentage increases are from 80 to 97 for the West, 81 to 95 for the North, 85 to 97 for the East and from 84 to 97 for the South.

Table 1

PROPORTION OF WOMEN IN CURRENTLY MARRIED STATE FOR SELECTED LEVELS OF MORTALITY, AGE AT MARRIAGE BEING 15 YEARS

Value of e_0^0	Proportion of currently married women in reproductive ages 15–44				
	U.N. Life Tables	Coale-Demeny Life Tables			
		West	North	East	South
30	.8099	.8038	.8101	.8462	.8373
	[100.0]	[100.0]	[100.0]	[100.0]	[100.0]
35	.8372	.8292	.8336	.8652	.8589
	[103.4]	[103.2]	[102.9]	[102.3]	[102.6]
40	.8621	.8528	.8550	.8828	.8786
	[106.5]	[106.1]	[105.5]	[104.3]	[104.9]
45	.8850	.8748	.8747	.8987	.8955
	[109.3]	[108.8]	[108.0]	[106.2]	[107.0]
50	.9053	.8952	.8919	.9128	.9131
	[111.8]	[111.4]	[110.1]	[107.9]	[109.1]
55	.9248	.9140	.9079	.9267	.9294
	[114.2]	[113.7]	[112.1]	[109.5]	[111.0]
60 [1]	.9420	.9317	.9239	.9403	.9444
	[116.3]	[115.9]	[114.1]	[111.1]	[112.8]
65 [2]	.9574	.9489	.9395	.9533	.9602
	[118.2]	[118.1]	[116.0]	[112.7]	[114.7]
70 [3]	.9717	.9651	.9544	.9661	.9734
	[120.0]	[120.1]	[117.8]	[114.2]	[116.3]

Note: Figures in parentheses are the percentages of the value corresponding to $e_0^0 = 30$

[1], [2], [3]: For U.N. Life Tables, the values of e_0^0 are 60.4, 65.8, and 70.2.

Average length of Married life within reproductive ages:

As a consequence of the phenomenon that greater proportion of women remain in the currently married state at all ages, there is an increase in the average length of marriage during the reproductive ages. From Table 2, it can be seen that in the case of U.N. life

tables, the average length of marriage within reproductive age for a girl marrying at age 15, increases from 19.6 years at $e_0^0 = 30$ to 28.6 years at $e_0^0 = 70$. Similar increases are from 19.8 to 28.4 years for the West, from 20.3 to 27.9 years for the North, from 21.7 to 28.5 years for the East and from 21.3 to 28.8 years for the South in the case of Coale-Demeny tables.

Table 2

AVERAGE LENGTH OF MARRIED LIFE ANTICIPATED FOR A GIRL MARRYING AT AGE 15, FOR SELECTED LEVELS OF MORTALITY

Value of e_0^0	Average Length of Marriage				
	U. N. Life Tables	Coale-Demeny Life Tables			
		West	North	East	South
30	19.6	19.8	20.3	21.7	21.3
	[100.0]	[100.0]	[100.0]	[100.0]	[100.0]
35	21.1	21.1	21.5	22.8	22.4
	[107.7]	[106.6]	[105.9]	[105.1]	[105.2]
40	22.4	22.3	22.6	23.7	23.5
	[114.3]	[112.6]	[111.3]	[109.2]	[110.3]
45	23.8	23.5	23.6	24.6	24.5
	[121.4]	[118.7]	[116.3]	[113.4]	[115.0]
50	24.9	24.5	24.5	25.5	25.5
	[127.0]	[123.7]	[120.7]	[117.5]	[119.5]
55	26.0	25.5	25.4	26.3	26.4
	[132.7]	[128.8]	[125.1]	[121.2]	[123.9]
60[1]	27.0	26.5	26.3	27.0	27.2
	[137.8]	[133.9]	[129.6]	[124.4]	[127.7]
65[2]	27.9	27.5	27.1	27.8	28.1
	[142.3]	[138.9]	[133.5]	[128.1]	[131.9]
70[3]	28.6	28.4	27.9	28.5	28.8
	[145.9]	[143.4]	[137.4]	[131.3]	[135.2]

Footnotes are the same as for Table 1.

Nuptial Fertility Rate:

The Nuptial Fertility Rates, adjusted for the change in currently married proportions, are presented in Table 3. The unadjusted rates are obtained as follows. The constant nuptial fertility schedule discussed earlier is applied to the age distributions of currently married women at different mortality levels and births obtained per thousand currently married women. These rates decrease as the value of e_0^0 increases. This is because of the fact

that more and more currently married women are concentrated at latter ages where the chance of reproduction is relatively small.

Table 3

GENERAL FERTILITY RATE FOR SELECTED LEVELS OF MORTALITY, AGE AT MARRIAGE BEING 15 YEARS

Value of e_0^0	Number of births per 1000 women aged 15–44 (G.F.R.)				
	U. N. Life Tables	Coale-Demeny Life Tables			
		West	North	East	South
30	182.2 [100.0]	180.7 [100.0]	181.8 [100.0]	189.7 [100.0]	187.0 [100.0]
35	187.7 [103.0]	186.1 [103.0]	186.7 [102.7]	193.6 [102.0]	191.6 [102.5]
40	192.7 [105.8]	191.0 [105.7]	191.1 [105.1]	197.1 [103.9]	195.7 [104.7]
45	197.2 [108.2]	195.4 [108.2]	195.1 [107.3]	200.3 [105.6]	199.2 [106.5]
50	201.3 [110.4]	199.5 [110.4]	198.6 [109.2]	203.0 [107.0]	202.8 [108.5]
55	205.1 [112.6]	203.3 [112.5]	201.7 [111.0]	205.7 [108.4]	206.1 [110.2]
60[1]	208.5 [114.4]	206.8 [114.4]	204.9 [112.7]	208.4 [109.8]	209.1 [111.8[
65[2]	211.6 [116.1]	210.1 [116.3]	207.9 [114.4]	210.9 [111.2]	212.2 [113.5]
70[3]	214.4 [117.7]	213.2 [118.0]	210.8 [116.0]	213.3 [112.4]	214.7 [114.8]

Footnotes are the same as for Table 1.

Adjustment in the nuptial fertility rate is effected by multiplying the unadjusted rates by the corresponding proportions currently married. The increase in the level of fertility is indicated by these adjusted nuptial fertility rates[6].

From Table 3, it can be seen that the general fertility rate, based on U.N. life tables, is 182.2 per thousand at $e_0^0 = 30$ and this rate increases to 214.4 per thousand by the time e_0^0 reaches about 70 years; showing an increase of 17.7 per cent. The computations on Coale-Demeny tables yield increases of 18 per cent for the West,

16 per cent for the North, 12.4 per cent for the East and 14.8 per-cent for the South.

Components of Fertility Change:

The variation in nuptial fertility rate can be accounted in this study, by two components: (i) variation in the age structure of currently married women and (ii) variation in proportion currently married. The nature of variation in the first component is the aging of population and has a negative effect on fertility while on the other hand the second component brings about an increase in the proportion currently married which reflects itself as increase in fertility. The net effect is the general fertility rate presented in Table, 3 which again is increasing.

The effect of variation in age structure is much less marked, in comparison to that caused by the variation in proportion currently married. The effect of the first component is reflected in the nuptial fertility rate unadjusted for proportions currently married; and this unadjusted rate declined from 225 to 220 while the adjusted nuptial fertility rate showed an increase ranging from 12.4 to 18.0 per cent.

Shift in Age at Marriage:

As can be seen from the foregoing results, the selection of the set of life tables does not seem to make marked differences. It was hence decided to perform the rest of the computations on the set of U.N. life tables only.

If the age at marriage for wife is fixed at 15 years, it was shown that the increase in the general fertility rate ranged from 12.4 to 18.0 per cent due to an increase in e_0^0 from 30 to about 70 years. If the age at marriage is fixed at more than 15 years, the per cent increase in fertility would naturally be less than the above values, as demonstrated by Table 4.

It would thus be interesting to see how much increase in age at marriage would be necessary to keep the level of fertility below a desired level despite the declining mortality. The level of general fertility rate at varying mortality levels are presented, for different fixed ages at marriage, in Table 4. The values are also graphed in Fig. 1.

Table 4

GENERAL FERTILITY RATE UNDER VARYING MORTALITY LEVELS AND VARYING AGE AT MARRIAGE, COMPUTED ON UNITED NATIONS LIFE TABLES

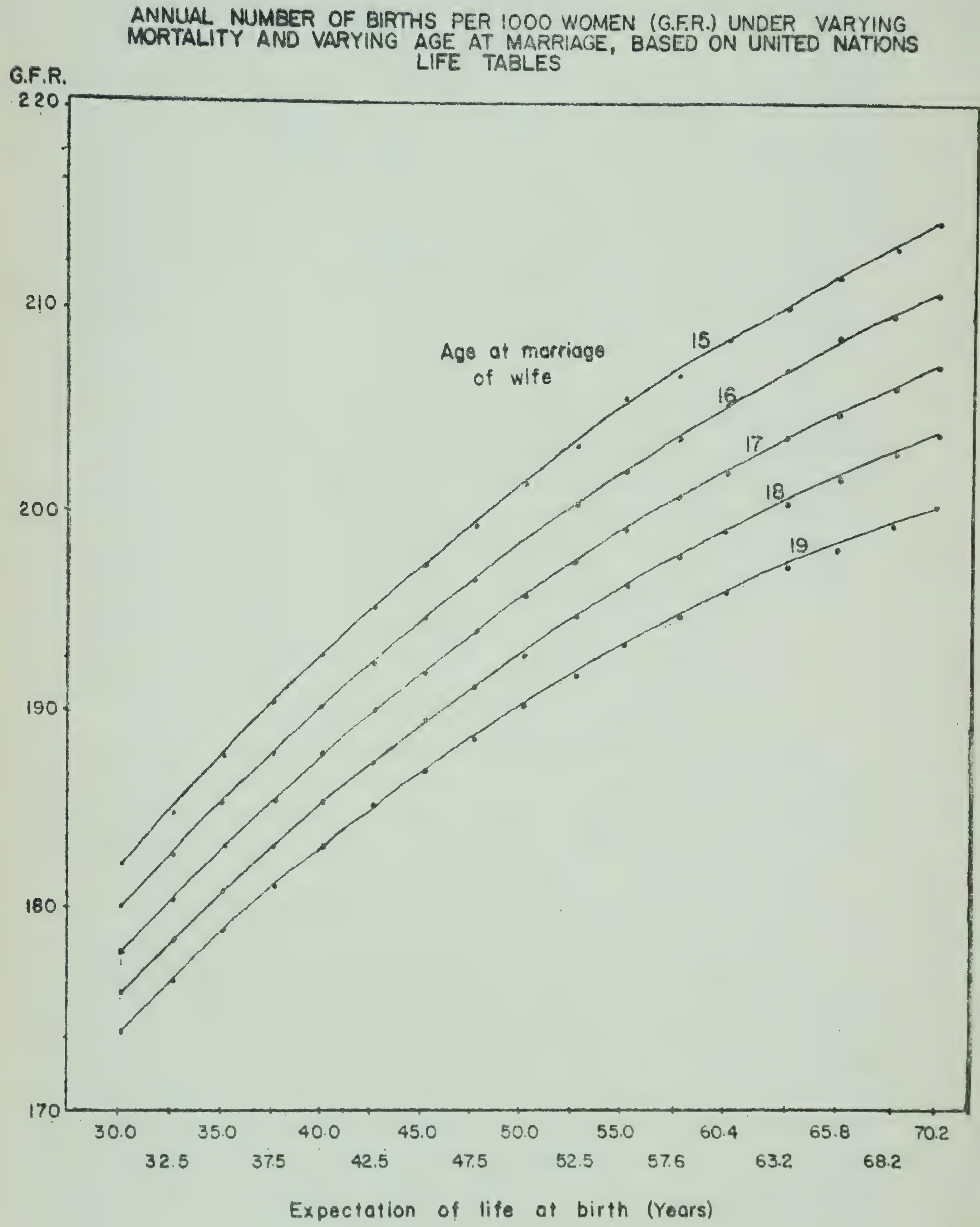
Value of e_0^0 (Years)	Number of births per 1000 women aged 15–44 (G.F.R.)				
	Age at marriage (in years)				
	15	16	17	18	19
30.0	182.2	180.0	177.8	175.8	174.0
32.5	184.9	182.6	180.4	178.3	176.4
35.0	187.7	185.3	183.1	180.9	178.8
37.5	190.3	187.9	185.5	183.2	181.0
40.0	192.7	190.2	187.7	185.4	183.0
42.5	195.0	192.4	189.9	187.4	185.0
45.0	197.2	194.6	191.9	189.4	186.9
47.5	199.3	196.5	193.8	191.1	188.6
50.0	201.3	198.4	195.6	192.9	190.2
52.5	203.3	200.3	197.5	194.6	191.8
55.0	205.1	202.1	199.1	196.2	193.2
57.6	206.9	203.8	200.7	197.7	194.6
60.4	208.5	205.3	202.2	199.1	195.9
63.2	210.1	206.8	203.6	200.4	197.2
65.8	211.6	208.3	204.9	200.6	198.3
68.2	213.0	209.6	206.2	202.8	199.4
70.2	214.4	210.9	207.5	204.0	200.5

From Table 4 and Figure I, it can be seen that an increase in the bride's age at marriage from 15 to 19 years would keep the general fertility rate down to about 200 per thousand women even if the general expectation of life at birth increases to about 70 years.

Comparison with Other Models

A similar study by means of a Simulation Model was undertaken by Ridley and others and the results were published recently[7]. Their model includes additional factors such as sterility and widow-remarriage. The age difference between husbands and wives was set at 7 years and the maximum average length of marriage at 30.7 years. The average length of marriage as shown by their study was 18.1, 21.7, 24.5, 26.9 and 29.0 years corresponding to e_0^0 being 31, 41, 51, 61 and 72 respectively. A comparison of these values with the findings in Table 2, of the present study seems to provide a satisfactory agreement.

Fig. 1


ANNUAL NUMBER OF BIRTHS PER 1000 WOMEN (G.F.R.) UNDER VARYING MORTALITY AND VARYING AGE AT MARRIAGE, BASED ON UNITED NATIONS LIFE TABLES
G.F.R.
220
210
200
190
180
170
Age at marriage of wife
15
16
17
18
19
30.0
32.5
35.0
37.5
40.0
42.5
45.0
47.5
50.0
52.5
55.0
57.6
60.4
63.2
65.8
68.2
70.2
Expectation of life at birth (Years)

The methodology in the present study permits analysis on women with varying ages at marriage and with different patterns of widow-remarriage. In the case of varying age at marriage, women with the same age at marriage can be conceived as a marriage-cohort and a synthesis of more than one such cohort is possible. For example, in a community where the marriage pattern, by the time e_0^0 becomes 70, is such that 25 per cent of all women marry at age 15, 50 per cent at age 17 and the remaining 25 per cent at age 19, the average length of first marriage at that mortality level will be 27.2 years on the basis of U.N. life tables. Similarly, widows remarrying at different ages can be entered, along with those marrying for the first time, at those ages of remarriage. The age-specific fertility rates of remarriages may be different from those of first marriages and data on fertility of remarriages, if available, could be used.

Also if rates of primary and age-specific secondary sterility are available, they could be included in the model and the length of marriage accordingly computed.

Conclusion

As a result of the general mortality decline, greater proportion of women remain in currently married state at all ages and this phenomenon shows itself in the increased length of marriage.

In view of the fact that greater proportion of women remain in marriage, the general fertility rate increases as mortality declines. However, on account of the increased sterility and the increased spacing between births towards the end of reproductive life and also due to the aging of the population, the proportionate increase in the general fertility rate is less than that of the average length of marriage for the same amount of decline in the general mortality.

An increase in the bride's age at marriage from 15 years to 19 years seems to keep the general fertility rate down to around 200 per thousand even if the general life expectancy at birth reaches about 70 years.

ACKNOWLEDGEMENTS

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NOTES

1 United Nations - Government of India, *Mysore Population Study* ST/SOA/ Series A/34; pp. 111-116.

2 "Widowhood and its duration", *Statistical Bulletin* Metropolitan Life Insurance Company, Sept. 1953

3 United Nations, Dept. of Economic and Social Affairs, "Methods of population projection by sex and age", *Population Studies* No. 25, New York, 1956.

4 Ansley J. Coale and Paul Demeny, *Regional Model Life Tables and Stable Populations,* Princeton University Press, Princeton, 1956.

5 Chandrasekaran, C. et al; "The Reproductive Patterns of Bangalee Women" All India Institute of Hygiene and Public Health (Unpublished).

Age-specific fertility rates per 1000 currently married women:

15-19	112.4
20-24	323.3
25-29	288.1
30-34	281.7
35-39	212.3
40-44	100.0

6 If age at marriage is 15 years, the number of all women and the number of ever-married women in the community are equal and thus the general fertility rate and the adjusted nuptial fertility rate become identical.

7 Ridley, Jeane Clare et al; "The Effects of Changing Mortality on Natality", *Milbank Memorial Fund Quarterly.* Vol. XLV, No. 1, Part 1, Jan. 1967, pp. 77-97.

The Effect of Declining Mortality on the Incidence of Widowhood and its Social Consequences

R. S. S. Sarma

Introduction

The life expectancy of a marriage is a very important piece of information from both an economic and a social viewpoint. Marriages may be dissolved by natural or legal means, that is, by mortality or divorce. The present study concentrates on marriages broken by the death of the husband. The trend in the age at which the marriage is broken through the death of the husband reveals the lengthening of married life (with its economic and social implications), which has been brought about by the increase in life expectancy among both males and females.

The dissolution of family by death of one of its members brings problems for the surviving members. Premature death of the breadwinner often creates a special hardship, to his widow as well as to his children. If the widow is young, there is the chance that she will remarry. The differences in fertility among some communities in India are to some extent explained by the taboo on widow remarriage. It is because of the fact that a proportion of the women of reproductive age are withdrawn from motherhood on account of this taboo[1].

The incidence of widowhood partly contributes to the problem of orphanhood, viz., those orphaned by the death of the father. Widows with small children may have to enter the labour force to supplement the inadequate resources. If a widow remarries, she may become separated from her children. In either case, they may become charges on the community. They may even pose special problems not only of an economic nature but also of social problems, like juvenile delinquency.

To measure the extent to which the incidence of widowhood poses social problems, the probability of widowhood by age, will be an essential tool. The probabilities of widowhood by age, the numbers of surviving widows at each age with increasing expectation of life, the extent of postponement of age at widowood caused by postponement of marriage, the average period of widowhood at different mortality conditions, etc., are attempted in this study. A very simple model has been utilised in order to study the trends in the proportion of surviving widows in the community, as mortality decreases and as age at marriage rises (there being the assumption for the sake of methodological procedure that marriages terminate only by death and that widows do not remarry).

Methodology

Number of widows surviving at an exact age:

1. To study the effect of declining mortality on the incidence of widowhood, we are going to confine the discussion to hypothetical communities where:

   a) All marriages are first marriages and there is no divorce.

   b) There is a difference of five years between the ages of the bride and the bride-groom.

   c) The differences in mortality according to marital status are considered nil, i.e., marital mortality is same as post or premarital mortality.

2. We start with a cohort of 100,000 females aged 15 and study their marital status at subsequent ages under different assumptions of age at marriage, and mortality level.

3. The ages at marriage which have been considered here are 15, 20, 25 and 30 for the bride, which imply by assumption (b), that the ages of the bridegroom are 20, 25, 30 and 35 respectively.

4. The mortality levels discussed here are those given by the U.N. Model Life Tables corresponding to joint life expectancy at birth for both sexes equal to 35, 50 and 60.4 years consecutively.

For example, we consider the case where the woman is married at age 15, to a man aged 20 under the level $e_0^0 = 35$. Theu corresponding to this mortality level, we have:

Number of females surviving from age x to age x+5, is given by :

$$l_x \quad {}_5p_x$$

where,

l_x = number of survivors aged x out of a cohort of 1,00,000 females started at age 15, and

${}_5p_x$ = probability that a female aged x will survive to age x+5.

The number of females surviving at age x+5 with husbands is:

$$l_x^s \quad {}_5p_x \quad {}_5p_{x+5}^1$$

where,

l_x^s = the number of females aged x surving with their husbands,

${}_5p_{x+5}^1$ = probability that a male aged x+5 survives to age x+10 and,

${}_5p_x$ = probability that a female aged x survivies to age x+5.

The number of widows surviving at age x+5 is given by :

$$l_x \quad {}_5p_x - l_x^s \quad {}_5p_x \quad {}_5p_{x+5}^1$$

By following this procedure, the number of widows surviving at different ages, has been worked out for different ages at marriage and at different mortality levels. The number of widows expressed as a proportion of the total ever-married women are presented in Table 1.

Probability of Widowhood during an interval of time : During a unit time of the married life of a couple, five types of events can take place, namely —

Table 1

PROPORTION WIDOWED UNDER THE CONSIDERATIONS OF DIFFERENT MORTALITY LEVELS AND DIFFERENT AGES AT MARRIAGE (BASED ON AN INITIAL COHORT OF 100,000 FEMALES STARTED AT AGE 15).

	Age at marriage = 15			Age at marriage = 20			Age at marriage = 25			Age at marriage = 30		
	e_0^0			e_0^0			e_0^0			e_0^0		
Age	35	50	60.4	35	50	60.4	35	50	60 4	35	50	60.4
20	0.0543	0.0306	0.0179									
25	0.1100	0.0614	0.0360	0,0589	0.0317	0.0184						
30	0.1680	0.0929	0.0546	0.1202	0.0643	0.0374	0.0652	0.0336	0.0194			
35	0.2305	0.1272	0.0757	0.1862	0.0996	0.0588	0.1353	0.0701	0.0412	0.0750	0.0378	0.0223
40	0.3009	0.1677	0.1020	0.2608	0.1414	0.0856	0.2145	0.1133	0.0685	0.1597	0.0824	0.0501
45	0.3803	0.2181	0.1380	0.3447	0.1934	0.1222	0.3037	0.1670	0.1058	0.2551	0.1380	0.0881
50	0.4679	0.2817	0.1873	0.4373	0.2590	0.1724	0.4021	0.2347	0.1570	0.3605	0.2081	0.1403
55	0.5639	0.3615	0.2543	0.5388	0.3413	0.2406	0.5100	0.3197	0.2264	0.4758	0.2960	0.2112
60	0.6650	0.4610	0.3455	0.6458	0.4440	0.3335	0.6236	0.4258	0.3210	0.5974	0.4058	0.3076
65	0.7678	0.5804	0.4641	0.7545	0.5671	0.4543	0.7391	0.5530	0.4441	0.7209	0.5374	0.4331
70	0.8640	0.7134	0.6081	0.8562	0.7074	0.6009	0.8470	0.6947	0.5935	0.8365	0.6841	0.5854
75	0.9377	0.8393	0.7595	0.9341	0.8342	0.7551	0.9300	0.8288	0.7505	0.9251	0.8228	0.7457
80	0.9813	0.9349	0.8885	0.9803	0.9328	0.8865	0.9790	0.9306	0.8844	0.9775	0.9282	0.8821
85*	0.9963	0.9838	0.9782	0.9961	0.9833	0.9778	0.9958	0.9828	0.9773	0.9955	0.9822	0.9769
90	0.9996	0.9978	0.9988	0.9996	0.9977	0.9987	0.9996	0.9977	0.9987	0.9995	0.9976	0.9987
95	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

* The proportions are worked out on the assumption, that for ages beyond 85, the survival probabilities of the life table of India, 1941–50, and the life tables of Japan for 1947 and 1952 are true in the case of model life tables corresponding to e_0^0 = 35, 50 and 60.4 respectively.

i) Both husband and wife may survive.

ii) Wife may survive and husband may die.

iii) Wife may die and husband may survive.

iv) Husband may die first—
both ultimately dying by the end of the interval of time.

v) Wife may die first—
both dying ultimately.

The events which contribute to our problem are (ii) and (iv). In the case of (iv), she lives as a widow for some time before her death. This consideration gains importance as the time interval becomes bigger.

Let ${}_xp_m$ and ${}_xp^1_{m'}$ be the probabilities of survival of wife and husband from age m and m′ to attain the ages m + x and m′ + x respectively, and ${}_xq_m$ and ${}_xq^1_{m'}$ those of death within that interval.

The probability of wife becoming widow during m to m + x of her age is given by:

$${}_xp_m \ {}_xq^1_{m'} \text{ according to event (ii)}$$

and

$$k \ {}_xq_m \ {}_xq^1_{m'} \text{ according to event (iv)}$$

where k is the probability of wife dying after the death of her husband under the condition that ultimately both of them will die during that interval of time. This probability can be in general taken to be 0.5. But more logically one can take into consideration, the idea that male mortality is generally higher than female mortality for adult ages. So k is taken as

$${}_xq^1_{m'} \,/\, ({}_xq_m + {}_xq^1_{m'})$$

Now the probability of a woman becoming widow during m to m + x years of her age is:

$${}_xp_m \ {}_xq^1_{m'} + k \ {}_xq_m \ {}_xq^1_{m'}$$

In actual procedure, five year age intervals are made use of. In usual notation, the above probability becomes:

$$ {}_5p_m \; {}_5q^1_{m'} \quad + \quad k \; {}_5q_m \; {}_5q^1_{m'} $$

where

$$ k = {}_5q^1_{m'} / ({}_5q_m + {}_5q^1_{m'}) $$

Median age at widowhood: If x_i be the number of married woman aged i, and p_i the probability of a woman becoming widow during her age i to i+5, the p_i x_i is the number of women becoming widows during i to i+5 years of their age.

$\sum_{i=a}^{\infty} p_i \; x_i$ is total number of ever-widowed women. These are distributed into five-year groups according to the age at which they are widowed (a = age at marriage of the wife).

With these frequencies, the median age at widowhood is calculated and is given for different values of e^0_0 and for different ages at marriage of the bride, in Table 4.

Average length of widowed life: If w_x and e_x are the number of widows and expectation of life at age x, then the mean length of widowed life is given by ;

$$ \int_a^{\infty} w_x \; e_x \; dx \Big/ \int_a^{\infty} w_x \; dx $$

Where a is the age at marriage of the wife. The above two being definite integrals in practice, the values are obtained by means of Gregory's Formula of Numerical Intergration[2].

Findings and Discussion

As a result of the decline in mortality, the proportion widowed in the population decreases at every period of life[3]. However, the extent of decrease is not the same at all periods of life. The younger the age, the more pronounced is this decrease. Nevertheless,

the absolute number of widows mounts up at the old age, because the female population at the older ages is growing faster than that of males.

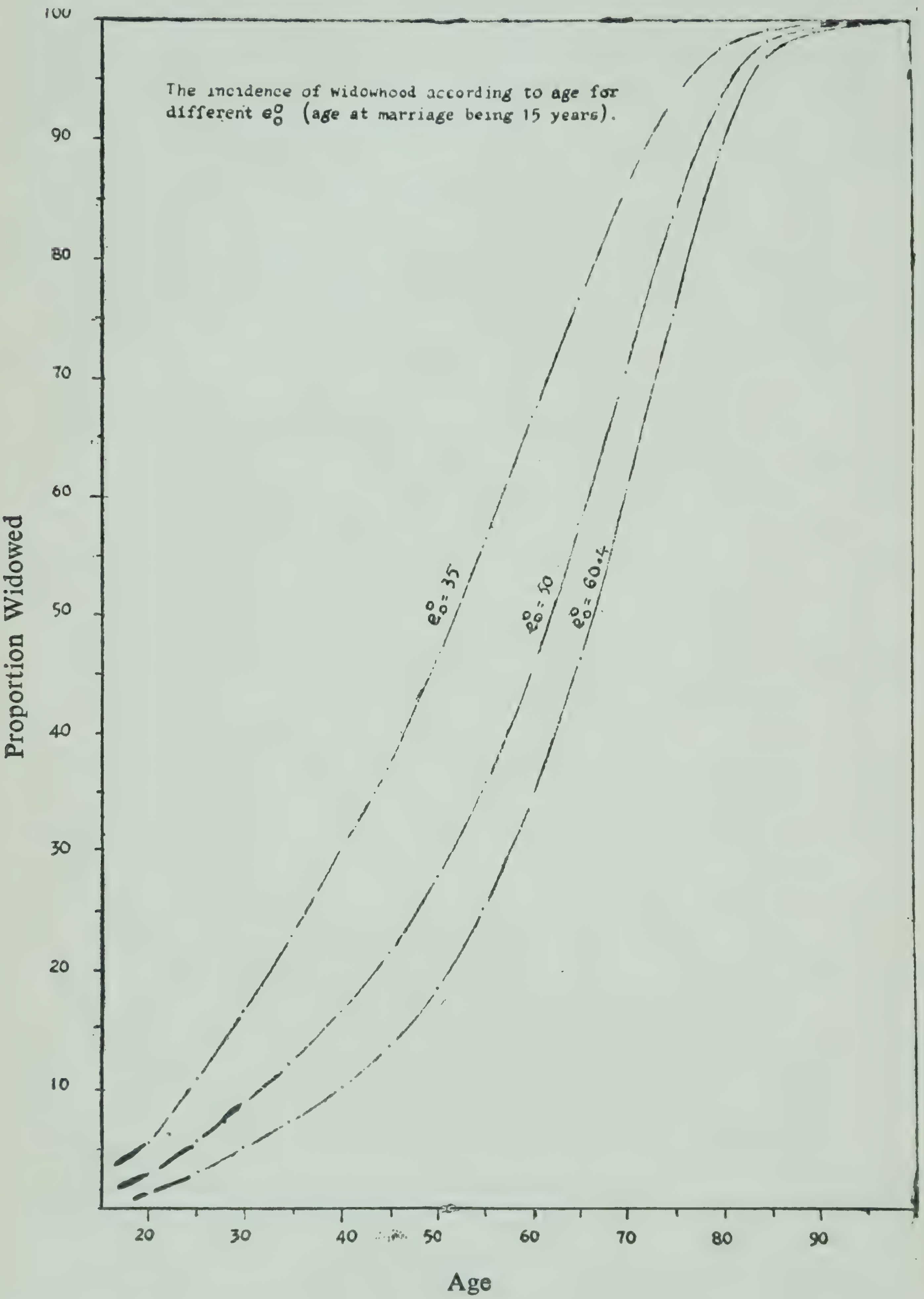
Widowhood-incidence curve: The proportion widowed according to age, follows an 'S' shaped curve — i.e., at a given e_0^0, the relative increase in proportion widowed with age is more in the case of middle age groups, than the younger or older groups. In the case of low expectations of life, the proportion of widows increases with age, in more or less a linear fashion as can be seen from Figure 1. But as e_0^0 increases, the 'S' shape of the curve is more pronounced.

Reproductive ages: As e_0^0 increases, we find a lateral movement of the curve in the reproductive ages — i.e., at the ages under 45, there is considerable reduction in the proportion widowed. The age at marriage being 15, the proportion widowed at ages under 45 is found to be 19 per cent at $e_0^0=35$. This decreases to 10 per cent when the expectation of life rises to $e_0^0=50$; the proportion again decreases to 6 per cent due to a further rise in expectation to $e_0^0=60.4$. This points out a considerable reduction in the widowhood incidence at these ages, showing thereby the likelihood of greater proportion of women passing their reproductive ages in conjugal life.

Incidence at older ages: At the older ages also, there are reductions in the proportion widowed, but the relative changes are small. About 88 per cent of the women aged 65 and over are widows at $e_0^0=35$ and these will be 76 and 68 per cent for e_0^0 equal to 50 and 60.4 respectively. The declining mortality results in the concentration of widowhood at the older ages. About 17 per cent of the total widows are found at ages 65 and over for $e_0^0=35$. This increases to 26 and 35 per cent in the case of $e_0^0=35$ and 60.4 respectively.

The relative importance of widwhood, for its social consequences, increases very sharply with each advance in age, as is evident from the fact that even under the improved conditions of mortality viz., $_0^0=60.4$, the widows comprise a little less than one-fifth of all women at ages 45-54, three-fifths at ages 65-74 and more than four-fifths at ages 75 and over[4].

The chances of eventual widowhood: As a consequence of the mortality decline, couples married today can look forward to a longer



The incidence of widowhood according to age for different e_o^o (age at marriage being 15 years).
$e_o^o = 35$
$e_o^o = 50$
$e_o^o = 60.4$
Proportion Widowed
Age
100
90
80
70
60
50
40
30
20
10
20
30
40
50
60
70
80
90

Fig. 1

life-time together, than those who married in years past, but at the same time, the likelihood that a wife will eventually become a widow increases significantly. The probability of eventual widowhood under the mortality conditions corresponding to $e_0^0 = 35$, is 0.5729 which rises to 0.6191 and 0.6548 at $e_0^0 = 50$ and 60.4 respectively, the age at marriage being 15 years. These probabilities are given in Table 2 for varying age at marriage.

Table 2

PROBABILITY OF EVENTUAL WIDOWHOOD FOR VARYING AGE AT MARRIAGE (THE AGE DIFFERENCE OF THE COUPLE BEING 5 YEARS)

Age at marriage of female	Probability of a Woman eventually becoming widow		
	$e_0^0 = 35$	$e_0^0 = 50$	$e_0^0 = 60.4$
15	0.5729	0.6191	0.6548
20	0.5494	0.6074	0.6486
25	0.5257	0.5957	0.6423
30	0.5015	0.5839	0.6359

Average period of widowhood: There is little difference in the average period of widowhood caused by the mortality decline. On the assumption of the age at marriage being 15, the average period of widowhood is 17 years for $e_0^0 = 35$ and 50, and 16 years in the case $e_0^0 = 60.4$. The findings based on the other assumptions of the age at marriage are presented in Table 3.

Table 3

AVERAGE PERIOD OF WIDOWHOOD

Age at marriage (Years)	Average period of widowhood (years)		
	$e_0^0 = 35$	$e_0^0 = 50$	$e_0^0 = 0.4$
15	17.1	17.1	16.0
20	15.8	15.8	15.0
25	14.7	14.7	14.1
30	13.6	13.7	13.3

It can be seen from the table, that the increasing age at marriage tends to reduce the average period of widowhood.

The effect of age at marriage : The age at marriage has a considerable influence on the widowhood incidence. The increase in age at marriage reflects a considerable decrease in the proportions widowed at the earlier ages, and this difference diminishes at the later ages and finally vanishes at the old age (Figure 2).

The median ages at widowhood for different ages at marriage are given in Table 4.

Table 4

MEDIAN AGE AT WIDOWHOOD

Age at marriage of female (Years)	Median age at widowhood		
	$e_0^0 = 35$	$e_0^0 = 50$	$e_0^0 = 60.4$
15	42.42	54.90	61.15
20	44.82	55.99	61.64
25	47.14	57.04	62.13
30	49.40	58.08	62.63

As can be seen, for an increase of every five years in age at marriage, there is almost a constant number of years of postponement in the median age at widowhood. On an average, there is an increase of 2, 3, 1.1 and 0.5 years in median age at widowhood, at $e_0^0 = 35$, 50 and 60.4 respectively due to a rise of five years in the age at marriage.

From Table 2, it can be seen that, as the age at marriage is raised, the probability of eventual widowhood gets reduced. This is in support of the fact, that the women who marry young have higher risk of widowhood than those who marry at an older age.

Also, as can be seen from the previous section, the average period of widowhood tends to decrease as the age at marriage is raised.

The Social Implications

Dependency and economic function of the bereaved family : Becoming a widow entails both the personal adjustment to bereavement as well as readjustment to a single life again. When

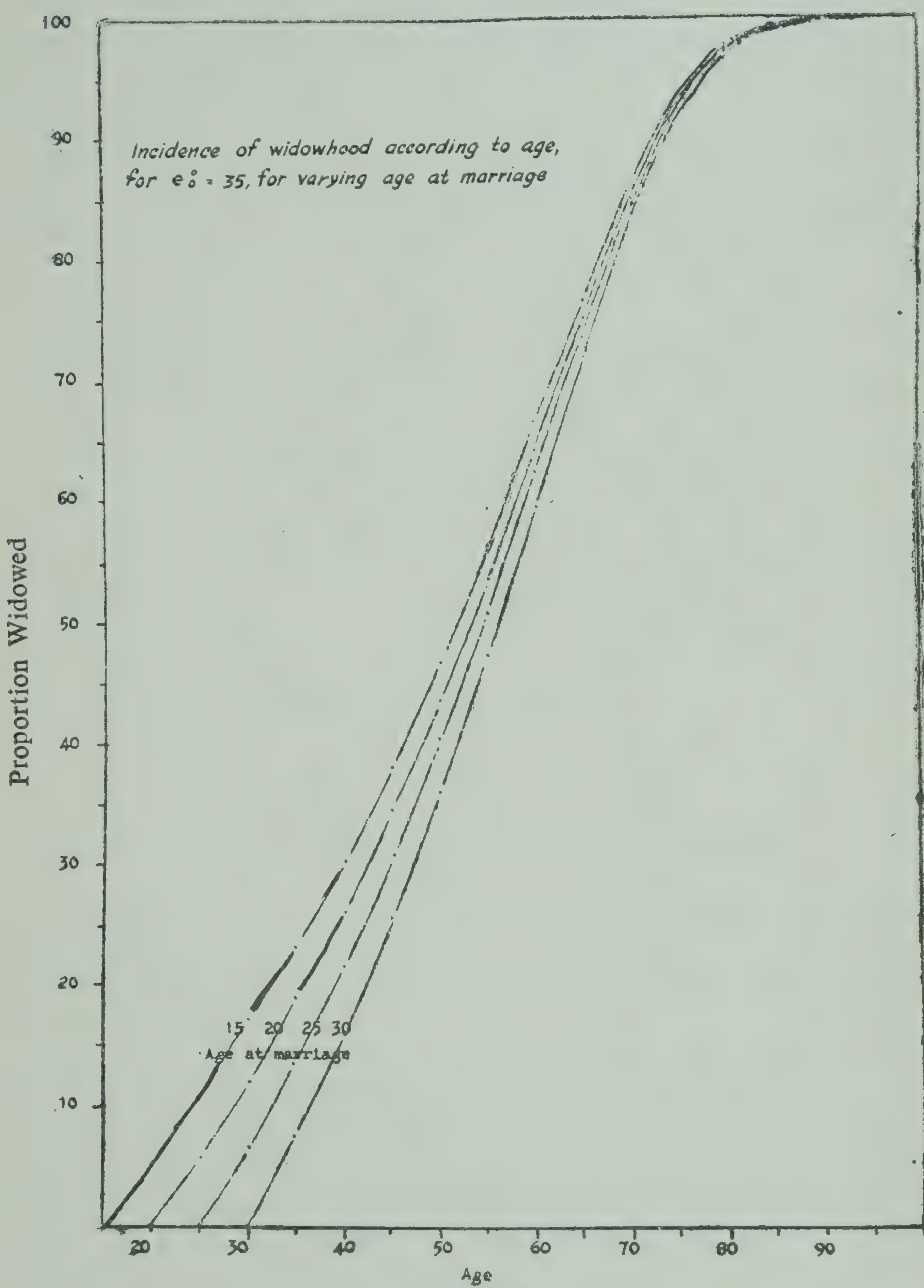

Incidence of widowhood according to age,
for $e_0^\circ = 35$, for varying age at marriage
Proportion Widowed
100
90
80
70
60
50
40
30
20
10
15 20 25 30
Age at marriage
20
30
40
50
60
70
80
90
Age

Fig. 2

the husband dies, the first problem which confronts the widow, especially if she has children, or if she has never worked, or not worked for many years, is a financial one. If she has children, it is often hard to provide for their care during working hours. This is because, in general, in the nuclear family economic system, the families are supposed to be self-supporting where adult members are responsible for the needs of the children. Of the great majority of the population living in family groups, it is the males in the productive years that are the prime supporters of the family. These are generally the husbands, and their earnings are likely to be the major source of family support.

In this particular aspect, the problems vary greatly with age. Among young widows the situation is especially serious, for a large proportion of them have dependent children in their care. Without sufficient income, the young mother often finds herself compelled to seek employment, without some sacrifice to her child-rearing duties. While women entering widowhood at the older ages are not likely to have dependent children, they are often faced with the problems of self-support. Moreover, the changes of securing employment at this stage of life are not too good, since these women have been out of the labour market for many years. Also the chances of remarriage for older widows are quite small. They may have to be economically dependent on their relatives or grown up children, if any.

Decreased family solidarity: The role of a family member exists in relation to fuctioning of the family as a unit. The death of the head of the household tends to disturb this unity. The shifting of the roles of various members under bereavement represents a reshaping of the family configuration. Family conflict may develop as a sequence to incompatible conceptions of the role of certain members under the new conditions. Such conflicts may result in a decreased family solidarity. Also, removal of authority of home, or support may lead to revision of family folkways. Maturity of children who lose their household head, may lead to individualism or turning to their own families. The crisis becomes a challenge for the widow to reorganise her life on a new basis.

The extended family system acts especially in the Indian setting, as social security for the aged dependants. There is a feeling that the extended family system is gradually disintegrating. The

concentration of widowhood towards old age brought about by the declining mortality demands attention in this respect.

The disintegration of joint family deprives the old widows of the institutionalised old age security. This poses a problem to the community, which can be met by creating some security policy regarding the protection of widows.

Children in a broken family: The disturbance in the intimate group life of the developing child is so great when his home life is broken, that special attention should be put forth to obtain the best adjustment. The loss of a parent removes from the child a gauge which has been standardized with wider social contacts and by which he may test the meandering of his attitudes towards life. With one of these controls gone, it is more difficult for the child to develop in conformity with established social usage. He consequently develops habits and reacts to social situations in ways which bring him into conflict with society. The extreme social restraints—the courts and remedial and penal institutions may be used in an attempt to adjust the difficulty. Due to death of the head of household, it may become necessary for the children to curtail the educational plans and even to give up the home. This particular aspect has got an association with the delinquent behaviour of the children.

While the financial loss resulting may have to be mitigated by insurance or such agencies, these behavioural aspects are to be taken care of by institutions like children's homes, orphanages, etc.

The findings of the present study indicate that the incidence of widowhood among young mothers decreases on account of the decline in mortality. This consequently may simplify to some extent, the problem of orphans.

Health care: Advances in medical therapy and surgery have contributed to mortality reductions by prolonging the life time of persons with physical impairments. In view of the decreased family solidarity and the economic dependency of the widows, the need for provision of free medical care and institutionalization may be essential.

Several writers have discussed the significance of marital role as a factor influencing personal adjustment. The emotional security

and social stability afforded by married life seem to make for low incidence of mental illness. The loss of spouse may be viewed as lending to disrupt the established modes of satisfying a variety of needs. It may not be out of place to point out a mental health survey in a noninstitutional population of females aged 65 and over, which shows that on a gross basis, the mental disorder rates for the widowed are significantly higher than those of the married[5]. This has been more or less true irrespective of the socio-economic status and physical health condition.

Reproduction and fertility: The proportion of marriages which remain unbroken by death has a direct bearing on reproductive performance of the community. In a study made in India, it was found that the death of the husband before the end of wife's reproductive age, reduced the average size of the family by about one child[6]. A greater prevalence of widowhood and earlier widowhood are supposed to have been responsible for the difference in average number of children born to women in rural as compared to urban areas.

American experience too, shows that according to the vital statistics of 1920, two per cent of the women that marry remain without issue merely due to the premature death of their husbands; these women would eventually have had a child if their husbands had lived to the end of the reproductive life[7]. Kingsley Davis has pointed out that the effect of the taboo on the re-marriage of widows in reducing the fertility in India amounts to about 15 per cent[8]

The drastic decrease of widowhood incidence in the reproductive ages brought about by the declining mortality is likely to result in increased fertility. This consideration gains importance while making efforts to bring down the birth rate. This in other words amounts to the need to accelerate the effective propagation of family planning.

NOTES

1 Kingsley Davis: "Human Fertility in India", *Americun Journal of Sociology.* Vol. 52, Nov. 1946.

2 Gregory's Formula of Numerical Integration is given by:

$$\frac{1}{w}\int_{a}^{a+aw} f(x)\,dx = \left(\tfrac{1}{2}f_0 + f_1 + f_2 + \ldots\ldots + f_{n-1} + \tfrac{1}{2}f_n\right)$$

$$-\tfrac{1}{12}\left(\Delta f_{n-1} - \Delta f_0\right) - \tfrac{1}{24}\left(\Delta^2 f_{n-2} + \Delta^2 f_0\right)$$
$$-\tfrac{19}{720}\left(\Delta^3 f_{n-3} - {}^3\Delta f_0\right)$$
$$-\tfrac{3}{160}\left(\Delta^4 f_{n-4} + \Delta^4 f_0\right) - \tfrac{863}{60980}\left(\Delta^5 f_{n-5} - \Delta^5 f_0\right)$$
$$-\tfrac{275}{24892}\left(\Delta^6 f_{n-6} + \Delta^6 f_0\right)$$

3 The incidence of widowhood is measured by the number of widows expressed as a proportion of the ever-married women of the corresponding age group and is hereafter referred to as 'proportion-widowed'.

4 A stable age-structure is constructed for each of $e_0^0 = 35.$ 50 and 60.4 with a constant G.R.R.=3 by means of the formula $c\ (x) = be^{-xr}\ p\ (x)$ (Ref. A.J. Lotka, "the Structure of a Growing Population", *Human Biology*, Dec. 1921). The results in the Sections 3.3 and 3.4 are obtained by applying the widowhood proportions to these stable age-structures.

5 Seymon S. Bellin and Robert H. Hardt, "Marital status and mental disorders among the aged" *American Sociological Review,* 1958.

6 United Nations, *Mysore Population Study,* Chapter 10.

7 A.J. Lotka, 'Sterility in American Marriages', *Proceedings of the National Academy of Sciences of the U.S.A.*, Vol. 14, 1928

8 Kingsley Davis, "Human Fertility in India"; *American Journal of Sociology* Vol. 52 Nov. 1946.

Impact of Variations in Mortality on the Length of Working Life*

U. P. Sinha

Introduction

Analysis of labour force statistics and its use in planning have become important in developing countries. In the recent years the mortality level (as measured by e_0^0) of the developing countries has shown improvement and consequently more people survive to higher ages. Likewise worker will survive longer and will be in the work force for a longer period. One way of measuring the period of stay of the worker in the work force is the length of working life which is conceptually similar to the expectation of life at birth. Since length of working life is dependent on the mortality pattern, an attempt has been made in this paper to study the changes in the length of working life with mortality level. The change in the length of working life may not be the same as the change in the mortality level (e_0^0) but may be smaller. Further, the change in the length of working life may be different at lower and higher levels of mortality which also has been studied in this paper through models.

Methodology

Wolfbein's method of estimating the length of working life is widely used and the same is well described in his paper[1]. For convenience sake the method is described here in short.

Suppose x, l_x, ${}_nL_x$ and e_0^0 have the same meanings as in the conventional life table. Let ${}_nW_x$ be the participation rate in the age group x to x + n. Then, the number of persons in work force in the age group x to x+n will be ${}_nL_x \cdot {}_nW_x$ and that at exact age x it will

* This is a revised version of the earlier paper with the same title presented at the "All-India Seminar on Models in Demographic Analysis", held at the International Institute for Population Studies, Bombay, February 17-19, 1969.

be l_x times the participation rate at the exact age x. Since the participation rate at the exact age x is not known, the number of persons in work force at exact age can be estimated by the relationship.

$$l_x^w = ({}_nL_{x-n} \cdot {}_nW_{x-n} + {}_nL_x \cdot {}_nW_x) / 2n$$

The above relationship holds good on the assumption that separation due to all causes are evenly distributed in the group. Further, to overcome the problem of accession in the work force in the earlier ages, Wolfbein has suggested the use of maximum participation rate at the earlier ages and it has also been assumed that there is no accession in the work force after reaching the age of maximum participation rate. Similarly, it is assumed that separation from the work force upto the age of maximum participation rate is due to mortality only and after that the cause "due to retirement" also comes into picture. The length of working life at age x is given by

$$e^o_{wx} = \sum_{t=x}^{\infty} {}_nL_t \cdot {}_nW_t \; / \; l_x^w$$

The above method, which we will call Wolfbein's method, considers a hypothetical population for the earlier ages as product of the maximum participation rate observed in the population and the life table population of the age group. In doing so we are including the period spent by the worker outside work force from the age for which the length of working life is calculated to the actual age of entry. An alternative method is to use person years spent in working force according to the observed participation rates. The number of workers at an exact age can be obtained by linear interpolation as given in Wolfbein's method or the product of persons at exact age and the participation rate of the exact age which may be taken as the average of the participation rates of the corresponding age groups.

Symbolically,

$$l_x^w = ({}_nL_{x-n} \cdot {}_nW_{x-n} + {}_nL_x \cdot {}_nW_x) \; / \; 2n$$

$$\text{or } l_x ({}_nW_{x-n} + {}_nW_x) / 2$$

Then, $$e^o_{wx} = \sum_{t=x}^{\infty} {}_nL_t \cdot {}_nW_t' \; / \; l_x^w$$

where ${}_{n}W'_{x}$ are the observed participation rates and ${}_{n}W_{x}$ are the participation rates observed in the population, except that for the earlier ages the observed participation rates are replaced by maximum participation rate.

Since the alternative method takes into account the period spent outside the work force for those workers who did not enter into the work force at the age for which the length of working life is estimated, the difference of the length of working life by the two methods will give us an idea of the average period spent outside the work force by such workers in the earlier ages and may be treated as period spent in preparation to enter into the work force from the exact age.

Selection of Participation Rates and Mortality Levels

It is clear from the above formula that for estimating the length of working life the participation rates and the life table of the country are necessary. In the present paper the participation rates are selected from the 'Demographic year Book, 1964'[2] and the life tables are selected from Coale and Demeny's Model Life Tables[3]. Three patterns of age specific participation rates in quinquennial age groups are selected such that for the same level of overall participation rate there will be an 'early', 'intermediate' and 'late' pattern of participation rates. The three patterns are represented by the participation rates (male) of Taiwn (1956), United States (1960) and Japan (1960). The overall participation rates of all ages, 15 & above and the standardized according to male life table population at $e_0^0 = 30.076$, model West are given in Table 1.

Table 1

OVERALL PARTICIPATION RATE OF SELECTED COUNTRIES WHOSE PARTICIPATION RATE SCHEDULES WERE USED

Countries	Year	Classification	Overall Participation Rate		
			All ages	15+	Standardized (all ages)
Taiwan	1956	Early	50.6	86.1	57.26
U. S. A.	1960	Intermediate	53.8	78.9	56.16
Japan	1960	Late	58.5	85.0	59.04

The observed overall participation rate of the three countries can be taken to be of the same level as the standardized overall participation rates are more or less of the same order.

The male life table population of Levels 6, 14 and 23 corresponding to $e_0^0 = 30.076$, 49.560 and 71.188 are selected for our purpose.

Result

The length of working life at age 15 at different levels of mortality and different patterns of age-specific participation rates by the two methods, period spent outside the work force and in preparation to enter into the work force from age 15 are given in Table 2.

Table 2

LENGTH OF WORKING LIFE AT AGE 15 AND OTHER RELATED MEASURES

Participation rate	e_0^0	e_{15}^0	Wolfbein's Method		Alternative Method		No. of years spent in preparation to enter work force
			Length of working life	Period of retirement	Length of working life	Period spent outside work force	
Taiwan	30.076	36.59	32.73	3.86	31.43	5.16	1.30
	49.560	46.64	38.95	7.69	37.59	9.05	1.36
	71.188	58.25	44.70	13.55	43.36	14.89	1.34
U. S. A.	30.076	36.59	34.46	2.13	31.06	5.53	3.40
	49.560	46.64	41.95	4.69	38.51	8.13	3.44
	71.188	58.25	49.30	8.95	45.86	12.39	3.44
Japan	30.076	36.59	35.17	1.42	32.18	4.41	2.99
	49.560	46.64	43.40	3.24	40.39	6.25	3.01
	71.188	58.25	51.90	6.35	48.89	9.36	3.01

It is evident from the above that the length of working life increases with the increase in mortality level (e_0^0). Similarly, the number of years in retirement also increases with e_0^0. Again, it shows that the participation rates have also some effect on the length of working life and is more visible at the higher levels of mortality.

The number of years spent in preparation to enter into the work force from age 15 forms an inverted 'U' shaped curve with slow decrease at higher levels of mortality. It also appears that Wolfbein's method of estimating the length of working life gives an higher estimate because the period in preparation to enter into the work force is included.

The change in the length of working life as measured by unit change in the length of working life per unit change in e_0^o is shown in Table 3.

Table 3

CHANGE IN LENGTH OF WORKING LIFE WITH RESPECT TO e_0^o

Country	Change in e_0^o from	to	Change in e_{wx}^o Wolfbein's method	Alternative method
Taiwan	30.08	49.56	.32	.31
	49.56	71.19	.27	.27
U. S. A.	30.08	49.56	.38	.38
	49.56	71.19	.34	.34
Japan	30.08	49.56	.42	.42
	49.56	71.19	.39	.39

It appears from Table 3 that the change in the length of working life increases more at low levels of mortality than at higher levels of mortality.

Conclusion

The results show that with the increase in the expectation of life at birth the length of working life also increases. But the change in the length of working life is not uniform. It is more effective at lower levels of mortality. For a developing country, where the level of mortality is increasing at a faster rate, it is more beneficial in the sense that with the same initial expenditure on education, training, etc., a workman will work for longer period. For example, at $e_0^o = 30$ a workman of Taiwan aged 15 years will be in labour

force for 32.73 years while at $e_0^o = 50$ he will be in labour force for 38.95 years. Thus, the increase in life expectancy has given opportunity to the worker to work for a longer period, assuming the same age-specific participation rates.

Secondly, with the increase in the expectation of life, the number of survivals at exact ages also increases. In the model life table at $e_0^o = 30$ out of every 100, 000 live births only 56, 770 reach the age of 15. Similarly, at $e_0^o = 50$ and 71,79,734 and 97,119 reach the age of 15. The number of years that a cohort of 100,000 live births will spend in the work force comes to 1,722,197; 2,898,170 and 4,072,482 years with the participation rates of Taiwan at $e_0^o = 30$, 50 and 71 respectively. In other words, a cohort of 100,000 live-births in Taiwan will be in work force for a longer period by 1,175,973 years at $e_0^o = 50$ than at $e_0^o = 30$.

The increase in life expectancy also increases the number of years in retirement, but there is no significant change in the number of years in preparation to enter in the work force.

Lastly, change in the pattern of age-specific participation rates has relatively minor effect on the length of working life at the same level of overall participation, specially at low levels of mortality.

ACKNOWLEDGEMENT

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NOTES

1 Wolfbein, S. L., "The Length of Working Life" *Population Studies*, Vol. III, No. 3, December 1949, pp. 286-294.

2 United Nations, *Demographic Year Book, 1964* U. N· Publication, Sales No. 65. XIII. 1, Newyork, 1965.

3 Coale, A. J. and Demeny, P., *Regional Model Life Tables and Stable Populations*, Princeton University Press, Princeton, New Jersey, 1966.

Life Tables and Projections

The Scope and the Limitations of Model Life Tables

Vasilios G. Valaoras

Development of Model Life Tables

The aim of model life tables is to make available the age specific mortality rates or the number of survivors to each age that may be expected under varying mortality conditions. If one can assume that mortality experience can be approximated by variation in the value of one parameter a single family of model life tables can be calculated. Attempts to summarize human mortality in a concise system of average sex-age patterns at various levels of force of mortality were repeatedly made during the last hundred years. Among them the United Nations Model life Tables were the first to present in a coherent form an integrated system of mortality patterns covering the entire range of variations observed in a large body of individual life tables from all around the world. The common observation that the age specific mortality curve maintains its general shape throughout the various levels of mortality, simply corroborates John Graunt's pioneer work who reported in 1662 about the "Numerical regularity" of deaths and births and the "Uniformity" and predictability" of many biological phenomena[1]. With this background theory in mind and in view of the recommendations by the population Commission, *first*, to provide approximate mortality levels for the majority of the world's populations so far lacking direct mortality information and *second,* to prepare population projections for future decades on a global scale, the Population Division of the United Nations embarked, some 20 years ago, to the task of developing a manageable mathematical tool in order to dispose the best it could with these obligations.

The technique and the method employed in the construction of those models are well known. Their weakness and limitations were explicitly stated in the following words: The models derived

"are intended to approximate averages of life table mortality rates, by sex and age, at the various levels of general mortality... The rather simple formulae and the broad generalizations which were used in the preparation of these model life tables, permit only the description of an average and more or less general pattern of observations over the whole range of variations represented. Finer variations in the patterns, as well as peculiarities that may occur in individual populations, are necessarily glossed over"[2].

As was expected, these models were used rather extensively and in the course of time several shortcomings or imperfections were pointed out by several scholars. Criticism was focused mainly on two points; *first*, on the use of infant (and/or the early childhood) mortality as the starting point of the system and *second,* on the formulae used (least square second degree parabolas) for computing mortality rates by age groups. On the basis of rates that were found in the immediately preceding age group, it was argued that infant (or early childhood) mortality is not the best rate for this purpose, since it is often exposed to spurious deviations because of incomplete or irregular registration of both births and infant deaths. Furthermore the system of parabolas may give erroneous predictions, mainly at the starting and the terminal segments of the resulting curve. Also experience showed that mortality schedules of some countries diverged markedly from the UN Model life tables.

Among the several attempts for improving or substituting the United Nation's Model Life Tables, the following are the most representative. Gabriel and Ronan[3], using the same data as the United Nations, but slightly different technique, derived least square estimates of ${}_5q_x$ by means of linear regressions on q_o. The resulting models showed lower values of e_0^0 for q_o ranging between 0.04 and 0.20.

Kurup[4] introduced the effect of differential exposure of countries to the technological improvements, which he believed to be of fundamental importance in the process of changing patterns of mortality. He stratified the countries (96 countries having one or more life-tables) from 1945 onwards) into five groups, in accordance with a composite index, made-up of the various components of levels of living (such as literacy levels, availability of medical doctors, food per capita

consumption expressed in caloric terms, levels of urbanization and of industrialization and the per capita national income). He then prepared five different sets of model life tables, each pertaining to the specified group of countries at different stages of development.

Finally Coale and Demeny[5], after a laborious study of the problem, produced the most significant contribution in this respect. Starting from 326 double (male-female) life tables, with the widest possible geographical and time-span coverage, arrived by a different methodology to a series of model life-tables, which subsequently were used for the construction of an impressive number (4992 in all) stable populations at various rates of population increase. Guided by the finding that "no single parameter could fit all reliably documented mortality experience", they divided the model life tables and the stable populations into four separate families with respect to the mortality patterns, which they leveled as: West, North, South and East regions. Their methodology was simple and convincing: linear regressions by least squares of ${}_nq_x$ and log ${}_nq_x$ on e^o_{10}, which was thought to be one of the most stable value in the series of expectation of life at various ages and levels of mortality. Twentyfour double (male-female) model life tables were thus prepared for each of the four families (region West, North, South and East), covering the range of expectation of life at birth for females, between e^o_0 : 20 and e^o_0 at 77.5 equal intervals of 2.5 years increment in e^o_0. For males, the values of e^o_{10} were selected on the basis of a typical relationship with the series of females (range of e^o_0 in males between 18.03 and 73.90 years). For the stable populations, the range of the rate of population increase, expressed first in R values varies from –10 to +50 and subsequently in GRR values, between 0.8 and 6.0, both series given in 13 unequally spaced intervals. Each of the nearly 5000 stable populations was supplied with the necessary parameters i.e. the resulting birth and death rates, the age structure and the more refined demographic indices and combinations therein.

The Coale-Demeny models won a striking popularity among demographers of the world and became a standard reference book in almost every Institution engaged in population analysis. The simple methodology, the clarity of the text and above all, the great number of experimental model populations, together with all pertinent parameters in each case, (though many of the stable populations given in

the book, are not likely to be duplicated by any population of today) account for the popularity of these models, which made a significant forward step in our understanding of mortality patterns and their demographic implications. Brass has constructed a two parameter system of model life tables which permits the use of clues about certain features of the age pattern of deaths experienced by a specific population. Thus a Brass model table can be constructed to yield a preassigned proportion surviving to each of two arbitrarily chosen ages. Thus if there are evidences of relative levels of child mortality and adult mortality, the Brass system of model life tables permits the selection of life table incorporating such a relationship[6].

However, the initial scope, as set-up by the United Nations in the early fifties i.e. the search for a set of model life tables which could conveniently be applied to countries with deficient or no mortality data, appears hardly to be fully met by these publications. In fact, the concept of dividing the world populations into four regions or several groups, each one with a somewhat different set of mortality patterns although supported by actual experience, does not well reconcile with the expected "uniformity" of mortality forces that are supposed to weigh upon the "single and unique" human species now living on this planet. It appears therefore that further consideration of this problem is still in order.

One or Several Families of Model Life Tables

A mathematical model able to rationalize population trends in all its components, i.e. fertility, mortality, age structure etc. for all countries and all times, may still lie in the realm of utopia. Relevant attempts from those of Gompertz and Makeham on the theory of mortality till the most composite work in recent times, amply support the validity of this statement. The main cause of disturbance comes out of the frequent finding that certain population at certain times, diverge sharply from the expected "normal," as it can be visualized at the present status of scientific knowledge. On the other hand, the fact that, for the last few generations, we live in a turbulent period of a violent demographic transition from a high fertility-mortality level towards a low one now may leave us with a certain trace of optimism in this respect. It may be presumed that mortality (and fertility) differentials, as they appear today, are byproduct of this

demographic transition. They probably were less evident or non-existant at the pre-transition era and actual observations testify about the gradual shrinkage of these differentials in populations approaching the final stage of balancing mortality and fertility at the lowest attainable level.

Mortality forces may be taken as springing out from two different sources, the biological constitution on one hand and the environmental hazards on the other. Genetic and/or congenital misfits and the wear and tear of the living tissues, which inevitably occur with the advancing age, account for the so-called biological mortality which forms the backbone of total mortality. Upon this, "environmental mortality" is heavily superimposed, consisting mainly of deaths due to epidemic (infections and parasitic) diseases, to malnutrition and to accidents (violent deaths). It may be reminded here that technology, and medical/public health progress affected, so far, only the environmental mortality leaving almost intact the basic mortality due to biological factors.

Unequal exposure of countries or population groups to the beneficial effects of technological and medical progresses, is the cause of mortality differentials, which lay almost solely within the realm of environmental causes of death. Hence, with the rather rapid diffusion of a single human culture, including technology and public health protection on a global scale, it may be expected that most (if not all) mortality differentials will eventually fall to insignificance or they will vanish entirely. According to this reasoning it may be concluded that, one set of model life tables which approaches the "average innate mortality patterns" is better and more manageable than many different sets, each one trying to approach regional or cultural deviations, which are unstable, incidental and temporary in nature.

In order to examine whether the above assumption really holds good or not we have plotted in the adjoining charts drawn on the semi-logarithmic paper the death rates (q_x) corresponding to different values of expectations of life at birth for each of the four families of models of Coale and Demeny. Two aspects of these charts are striking. Firstly, the difference between the different regional models become smaller as the expectancy of life at birth increases. Secondly,

the male female differential seems to be similar in all the four regional models especially at higher levels of expectancy of life at birth. Despite these similarities between these four regional models, there are some interesting contrasts too. In the West and South Models, for example, q_5 is higher for females than for males at low levels of expectancies of life at birth, but this gradually changes and from expectancies of life 55 years onwards, q_5 for males exceeds that for females. A similar reversal of the sex differential takes place at age 45 in the East Model and at age 35 in the North Model. Similarly, the sex differential in q_{10} is reversed from one of higher female rate to one of higher male rate at about age 60 in the West and East Model and at about age 55 in the North Models. A peculiar feature noticed in the South Model is the higher mortality at age 1-4 compared to age 0 when expectancy of life is low. This seems to be an artefact of the data used in the model.

All these may indicate that real geographical differences do not exist except for the differences in socio-economic development. It may therefore be right to assume that mortality patterns tend to converge to a unique form as the socio-economic progress is diffused and approaches uniformly among all the peoples of the world. The credit for this coming event, goes to the World Health Organization and the other United Nations' Agencies whose main preoccupation is the promotion of health and the raising of living standards on a universal scale. For the demographers, it may serve as a hint and a challenge to solve the problem of formulating a suitable law of mortality to which man, as a single species and with a similar culture is normally exposed.

Final Remarks

Model life-tables and stable population are similar to population projections, which are designed as simple guiding lines, with little or no expectation that living population can or will duplicate exactly the prescribed theoretical trends. It is a common knowledge that biological phenomena are not well adapted to quantitative analysis and almost never follow the lines of an artificial model. Their reactions to environmental stimuli are often sharp and unpredictable, but always with a tendancy to fall back to their "normal dynamic stability" after the primary shock is over.

Differentials in mortality as they are observed today, may be taken as biological reactions to the stimuli of technological and public health advances. They are not stable or permanent, and their introduction to mathematical models, represent perhaps an unnecessary and futile refinement. All it is needed in this enterprise is to approximate to the best of our knowledge the average course of mortality patterns which are reasonably applicable to all major contemporary human population. Special parameters may (or may not reliably) be computed, with the view to modify the average pattern in particular cases, but the derivation of the proper parameters is much more hazardous than that of the basic patterns. With respect to the methodology, a simple formulae such as a linear regression between ${}_{n}q_{x}$ and e_x^o at key points throughout the age span, yields perhaps better results than a complicated one. There is no ideal mathematical formulae to exactly fit biological phenomena; both simple and complicated formulae may be equally wrong, the latter despite the greater effort. Finally, it is advisable that model life tables be revised periodically—every five or ten years—taking into account the continuously accumulating experience and striking out weaknesses that become evident in previous models.

NOTES

1 United Nations, *The Determinants and Consequences of Population Trends*, 1953, page 25.

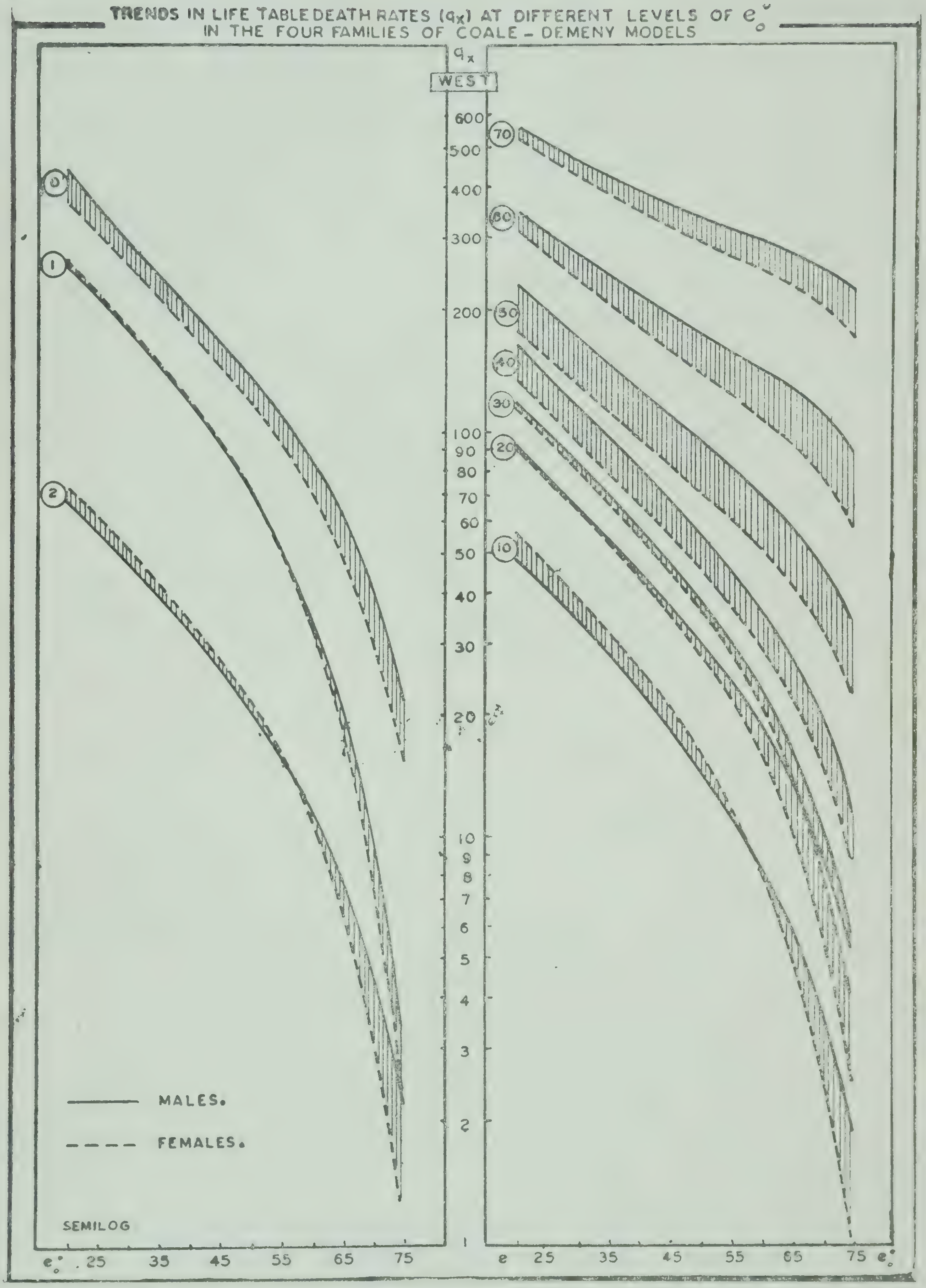
2 United Nations, *Age and Sex Patterns of Mortality. Model Life Tables for Under-developed Countries*, 1955 page 20 and 21.

3 K. Gabriel and Ileana Ronen, "Estimates of Mortality from Infant Mortality", *Population Studies*, Nov. 1958.

4 R. S. Kurup: "Recent Trends in World Mortality and Application for a Revised System of Model Life Tables". Chicago 1964 (unpublished disertation)

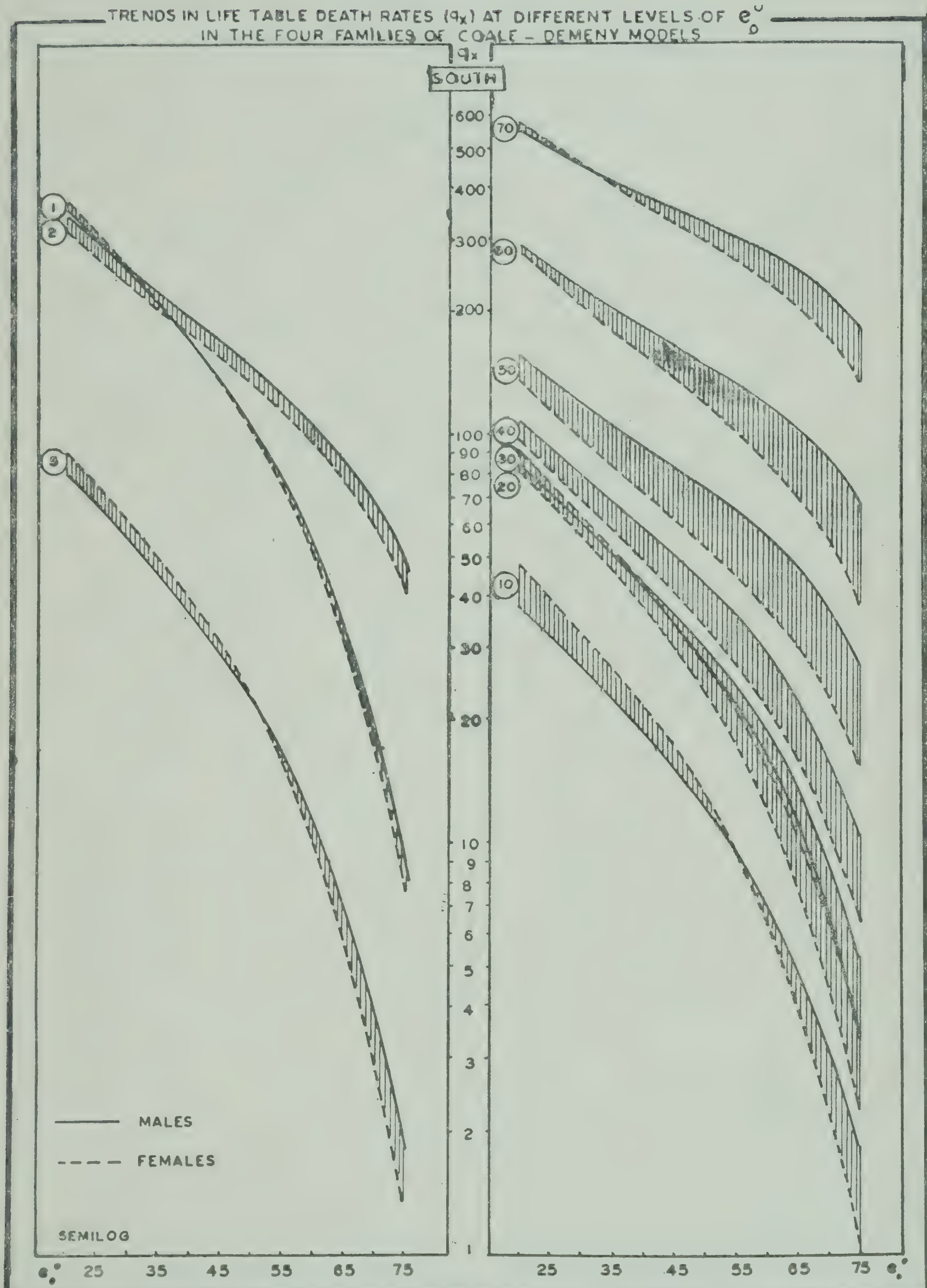
5 A. Coale and P. Demeny: *Regional Model Life Tables and Stable Population*, Princeton University Press, New Jersey, 1966.

6 See William Brass et al, *The Demography of Tropical Africa*, Princeton. N. J. Princeton, University Press, 1968, pp. 342 – 440.



TRENDS IN LIFE TABLE DEATH RATES (q_x) AT DIFFERENT LEVELS OF e_o^o
IN THE FOUR FAMILIES OF COALE - DEMENY MODELS
q_x
WEST
MALES.
FEMALES.
SEMILOG

Fig. 1



TRENDS IN LIFE TABLE DEATH RATES (q_x) AT DIFFERENT LEVELS OF e_0^0
IN THE FOUR FAMILIES OF COALE – DEMENY MODELS
q_x
SOUTH
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
1
2
5
70
60
50
40
30
20
10
MALES
FEMALES
SEMILOG
e_0^0
25
35
45
55
65
75

Fig. 2

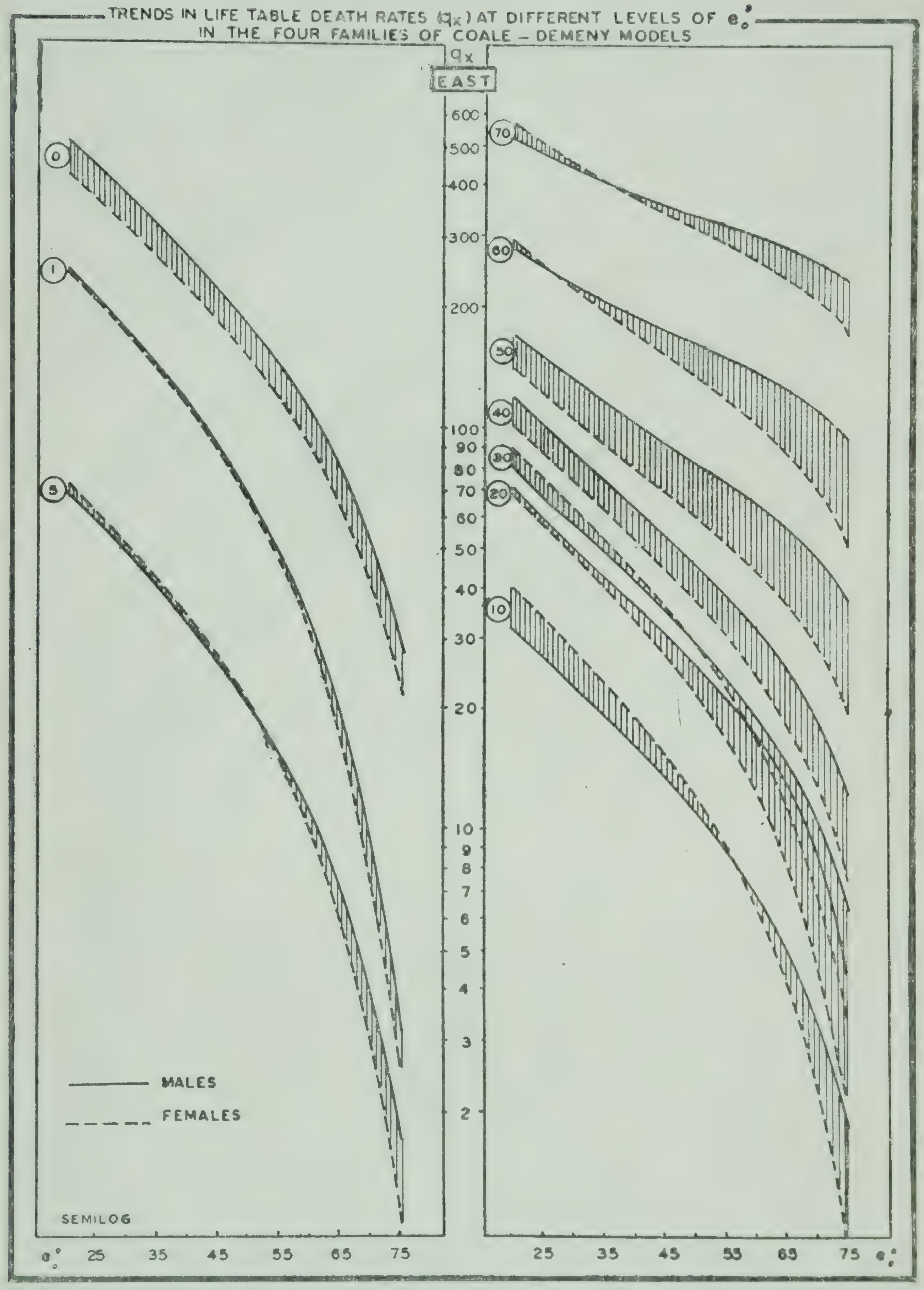

TRENDS IN LIFE TABLE DEATH RATES (q_x) AT DIFFERENT LEVELS OF e_0^o IN THE FOUR FAMILIES OF COALE – DEMENY MODELS
q_x
EAST
MALES
FEMALES
SEMILOG
e_0^o

Fig. 3

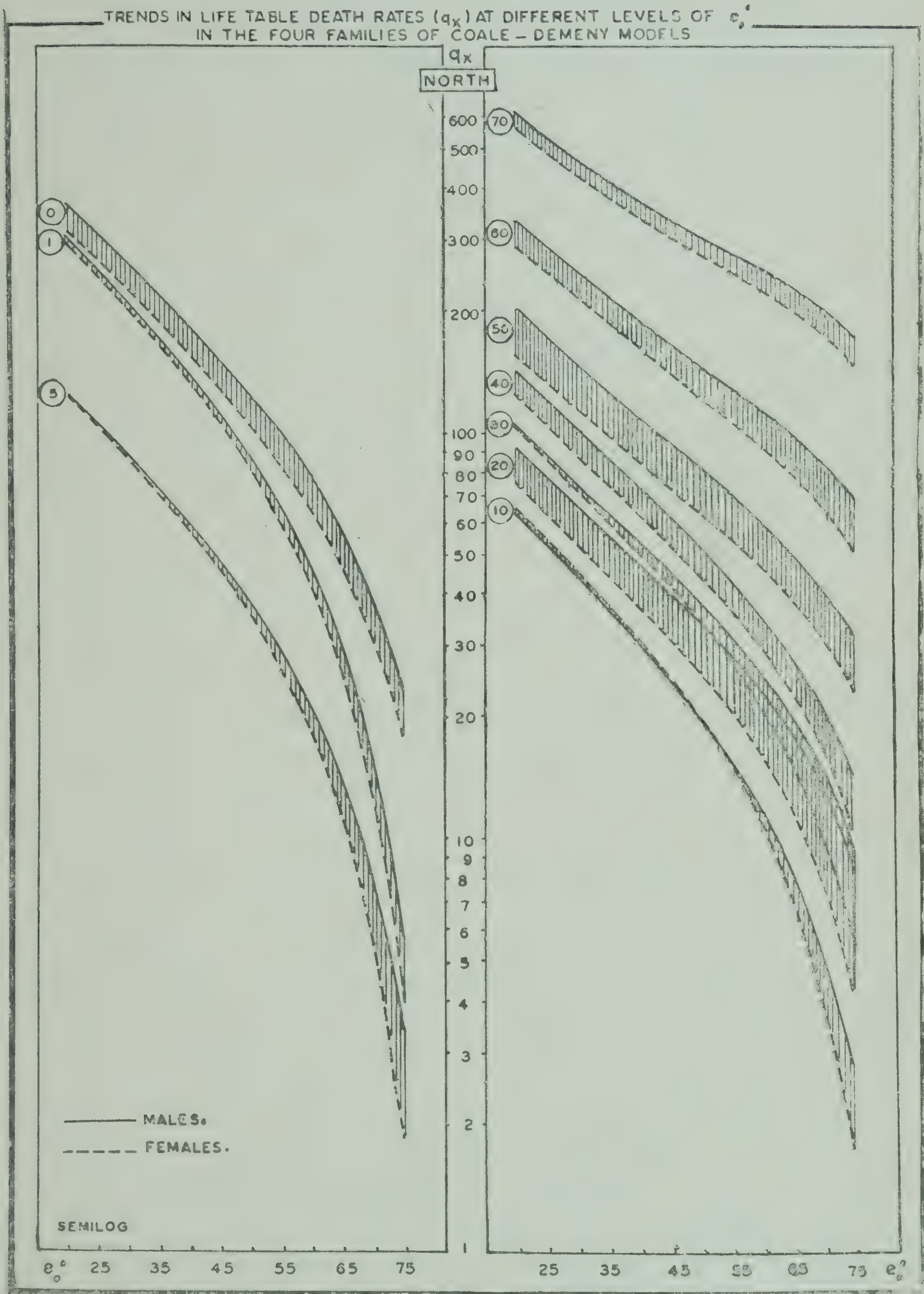

TRENDS IN LIFE TABLE DEATH RATES (q_x) AT DIFFERENT LEVELS OF e_0^0
IN THE FOUR FAMILIES OF COALE – DEMENY MODELS
q_x
NORTH
0
1
5
70
60
50
40
30
20
10
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
MALES.
FEMALES.
SEMILOG
e_0^0
25
35
45
55
65
75

Fig. 4

An Approach to the Revision of the United Nations Model Life Tables

R. S. Kurup

Introduction

In this paper the evolution of mortality models is briefly reviewed and the recent attempts at building model life tables to summarize the mortality patterns in different parts of the world are examined. The paper also presents an approach to the revision of the United Nations System of Model Life Tables, so as to reflect the realities of the present day mortality situation in different parts of the world.

The models employed in mortality studies have been developed for three purposes, classification, description and analysis. The techniques for the analysis of mortality have evolved round the mortality table. The computation of the first table for an entire nation is attributed to Per Wargentin for Sweden for the period 1755-63 published in 1776. These life tables showed that the death rate of males exceeded that of females. The model which emerged is that of a stationary population having a higher death rate for males as compared to those of females. There was, however, no systematic attempts to use these models in research. These were used for purposes of life insurance and annuities only. Sussmilch, Thomas Short, Milne Kersseboom and Deparcieux exercised great ingenuity in life table construction. Daniel Bernouille in 1760 treated mortality as a continuous variable with the force of mortality considered in an infinitesimal interval of time. De Moivre (1725), Gompertz (1825) Makeham (1860) and others were interested in general formula of mortality applicable to the whole life span. Lexis (1875) and Karl Rearson (1897) investigated the distribution of deaths at advanced ages. As a result of passing of public health laws in England and other parts of Europe, interest in national life tables was aroused and most countries with the necessary data came forward with life tables as models of mortality behaviour.

These life tables were used for predicting future courses of mortality and for purposes of population projections.

The analysis of mortality has been further extended to the construction of cohort life tables. Specific patterns or models emerged in respect of mortality differentials by sex, age, ethnic or racial origin, marital status, occupation, social class, size of community and place of residence (urban-rural). Euler in 1760 and Lotka during the initial decades of the present century extended the stationary model to the stable model which has provided a very useful tool for demographers for analytical research.

Models Prior to United Nations Model Life Tables

Notestein and others [1] examined the record of past changes in mortality on the basis of the trends in life table death rates omitting the experience of the war years. The mortality tables used were those of the European countries having a series covering 25 or more years and those of Australia and New Zealand. Two generalizations having predictive significance were arrived at.

1. In past European experience covered by the life tables when death rates were high they were declining rapidly; when they were low, they were declining slowly. In other words the downward slope of the death rate was closely and positively correlated with the magnitude of the death rate.

2. In past European experience, the relation of the height of mortality for a given age-sex group to the downward slope of the rate was much the same at the various periods studied. In other words, the height-slope relation was substantially independent of time.

In view of these life table death rates were used to derive curves that described the average course through which mortality had moved from high to low in European experience since 1870. Mortality rates were projected by locating the values of the most recent life tables on the appropriate curve and by reading forward on the curve. The results gave materials for constructing life tables for each country for future dates.

In the United Nations Study on *World Population Trends*[2] an examination of existing data on crude death rates and mean

expectation of life in various countries for which information was available yielded a rough relationship which could be used to estimate the expectation of life at birth from the crude death rates for other countries.

By an examination of the recent trends in several developing countries the United Nations concluded that "Evidence of a firm trend of falling deth risks can be established with certainty for the great majority of world regions. Because of the cheap and effective means of disease control, mortality may decline rapidly even if it is initially high. An annual gain of half year in the expectation of life at birth is now normal, at least for expectations of life ranging from 30 to 55 years[3].

Stolnitz[4] derived a number of general proposition on the mortality trends and differentials. He found that Western populations in their period of initial industrialization have generally provided a poor prognosis of subsequent trends. Within the West itself, developments in the last part of the 19th century were very different from those during the earlier decades. Socio-economic differences are not probably the main explanation for the contrasts. Also in contrast with the West, the recent improvements in life expectancies in the developing countries are the result of innovations in public health rather than any substantial improvements in the levels of living.

UN Model Life Tables

The methodological exercises culminated in the construction of model life tables by the U.N. by fitting parabolas connecting successive life table mortality rates in pairs [5 6]. From the resulting curves the rates for specified expectations of life at birth were derived. The reliability of the model life tables was tested by comparing the shape of selected observed life tables with the model ones. Also, by plotting the actual observations and the trends of the relation between childhood mortality and expectation of life at birth, the accuracy of the model life tables was checked. It was admitted in the U.N. study "that the rather simple formulae and broad generalizations which were used for the preparation of these model life tables permit only the description of an average and

more or less general pattern of observations over the whole range of variation represented. Finer variations in the pattern as well as peculiarities that may occur in individual population, are necessarily glossed over".

In 1958, Gabriel and Ronen [7] evaluated the reliability of the U.N. Scheme. For this, they computed the deviations of the estimates from the observed values of the expectations of life at birth and found that the model life tables tend considerably to over-estimate the expectation of life. Actual comparisons of model life tables estimates with corresponding least squares estimates showed that the model life tables underestimate mortality most severely when the expectation of life is about 55 years and overestimate mortality when it is below 35 years or so.

Next, they obtained least squares estimates at each age by linear regression connecting infant mortality rate. They constructed a confidence interval for the expectation of life assuming a normal distribution. The wide confidence interval they obtained showed how unreliable these estimates would be even though the method yielded unbiassed minimum variance estimates.

A Family of Model Life Tables

The studies reviewed above did not consider the effects of differential exposure of countries to the technological improvement that are fundamental to the changing patterns of mortality. Various scholars have proposed a stratifcation of countries or communities according to socio-economic and health conditions. Notestein[8] stressed the importance of studying mortality in the context of the changes in socio-ecnomic conditions. Irene B. Taeuber[9] also pointed out the need of analysis of mortality in the socio-economic context. The author in his recent paper stratified the countries recording to socio-economic and health conditions so far as data permitted and analysed mortality trends in these strata[10]. Also, it was noticed that mortality trends before the second World War and after the War differed. It was felt necessary that a new model life tables should be constructed on the basis of data from 1945 onwards. The following paragraphs deal with the procedures adopted for stratification of countries and the construction of model life tables.

Altogether 96 countries for which relevant data are avilable have been considered for the stratification. The composite index of socio-economic and health conditions was built by first forming the component indices of level of living, literacy standard, level of urbanization, level of industrialization and avilability of medical and public health facilities. In regard to the index of level of living, the national product per capita, though a controversial one is used along with the calorific equivalent of food consumed per capita. For most of the countries data for a long period are not available for constructing a dynamic index. Data available in Ginsburg[11] for the 1950's have been used for forming the indices.

The index of literacy standard is taken as the per cent of persons who are literate. In regard to the urbanization index, the percentage of persons in towns or cities with population above 20,000 is considered. The percentage of persons engaged in manufacturing industries is taken as the index of industrialization. The number of doctors per 1000 population which alone is available is taken as index for health conditions. A composite index obtained by adding the ranks of each country according to the value of the above indices has been used for the stratification of countries. The countries were divided into five groups which are given below. It may be remarked here that it is not believed that this stratification is very perfect but whatever other stratifications which may be made will not change the positions of the various countries much vis-a-vis others. Also the conditions in the countries amply justify their being grouped as explained here. The scheme of ranking the countries is given as Appendix 1.

Stratum	No. of Countries	Name of Countries
1	14	Australia, USA, Canada, New Zealand, Switzerland, Luxemburg, Sweden, Iceland, France, U.K., Norway, Denmark, West Germany and Netherlands.
2	15	Belgium, Finland, Venezuela, USSR, Uruguay, Czechoslovakia, Israel, Austria, Ireland, Poland, Italy, Hungary, Argentina, Cuba and Japan.

3	17	Puerto Rico, Union of South Africa, Panama, Columbia, Rumania, British Guinea, Costa Rica, Yugoslavia, Hong Kong, Bulgaria, Lebanon, Brazil, Spain, Greece, Mexico, Chile and Paraguay.
4	22	Cyprus, Surinam, Malaya, British North Borneo, Turkey, Jamaica, Nicaragua, El-Salvador, Dominican Republic, Equador, Portugal, Phillipines, Iraq, Guatamala, Peru, Honduras, Egypt, Ceylon, Syria, Taiwan, Thailand and South Korea.
5	28	Algeria, Saudi Arabia, Morocco, Ghana, Rhodesia, Zambia, South Vietnam, Tunisia, Indonesia, Siberia, Iran, Sudan, Congo, Jordan, Libya, India, Nigeria, Former Portugese Africa, Bolivia, Former British East Africa, Former British West Africa, Former French Equatorial Africa, Paskistan, China, Afghanistan, Ethiopia, Burma and Nepal.

The five strata of countries can be classified in terms of economic development as

(I) the most developed countries

(2) the developed countries

(3) countries of medium development

(4) already developing countries and

(5) recently developing countries.

Analysing the mortality trends in the recent decades in the various classes of countries certain broad features have been delineated. The stratification herein suggested thus provide a model for the study of mortality trends.

Revised Model Life Tables

Model life tables were prepared for each of these strata by considering the available life tables from the year 1945 onwards. Each age-specific rate except the first two was connected to the previous two rates by a linear relation whose constants were obtained as least squares estimates. The first two rates were connected by an exponential relation as seen from the trend of the values in the various strata. The main functions of the life table were calculated by assuming the infant mortality rates, based on the empirical relations worked out, The values of the survival probabilities are given in Appendix II for the recently developing countries for selected levels of expectation of life at birth for males and females. The other values are not reproduced here as they run into several pages. The survival probabilities for any intermediate level can be computed by linear interpolation.

A comparison of the United Nations Model Life Tables values with the revised ones shows that many of the defects in the UN tables do not appear in the revised ones.

APPENDIX I

SCHEME OF RANKING ADOPTED FOR STRATIFICATION

1. Per capita Gross National Product	Rank
Above — 1000$	1
700 — 1000$	2
500 — 700 $	3
300 — 500 $	4
200 — 300 $	5
100 — 200 $	6
Below — 100 $	7

2. Per capita consumption of food	
Above 3000 calories	1
2500 cal. — 3000 cal.	2
2000 cal. — 2500 cal.	3
Below 2000 calories	4

3. Per cent urban in cities with 20, 000 population or more	
50 % and above	1
40 % — 50 %	2
30 % — 40 %	3
20 % — 30 %	4
10 % — 20 %	5
Below 10 %	6

4. Literacy standard	
90 % and above	1
75 % — 90 %	2
50 % — 75 %	3
40 % — 50 %	4
30 % — 40 %	5
20 % — 30 %	6
10 % — 20 %	7
Below 10 %	8

5. Per cent Industrial (engaged in Manufacturing industries)

10 % and above	1
7 % 10 %	2
2 % 7 %	3
Below % 2 %	4

6. Number of Doctors per 1000 persons

1 and above	1
.5 to .1	2
.1 to .5	3
.05to .1	4
Below .05	5

7. Sum of ranks (Composite index)

6 — 11	1
12 — 16	2
17 — 21	3
22 — 27	4
28 and above	5

APPENDIX II

SURVIVAL RATIOS OF MODEL LIFE TABLES (STRATUM V)

MALES

Age in Years	EXPECTATION OF LIFE AT BIRTH 47.90	46.04	43.73	42.11	39.94	37.02	35.05	33.08	31.25	29 62	26.44	24.99
Births	.84700	.83657	.81581	.80548	.79007	.76456	.74430	.72416	.70415	.68427	.64483	.62527
0–4	.95159	.94860	.94261	.93693	.93518	,92779	.92185	.91591	.90995	.90395	.89174	.88550
5–9	.98653	.98586	:98456	.98394	.98301	.98153	.98040	.97929	.97825	.97720	.97520	.97422
10–14	.98635	.98569	.98437	.98375	.98282	.98133	.98020	.97909	.97804	.97698	.97498	.97400
15–19	.97892	.97704	.97441	.97292	.97034	.96627	.96363	.96033	.95720	.95471	.94861	.94580
20–24	.97220	.96900	.96551	.96282	.95844	.95159	.94736	.94223	.93687	.93290	.92241	.91764
25–29	.96723	.96345	.95970	.95630	.95117	.94311	.93816	.93256	.92631	.92169	.90947	.90392
30–34	.96002	.95541	.95093	.94672	.94046	.93064	.92462	.91789	.91028	.90466	.88979	.88305
35–39	.94962	.94383	.93855	.93303	.92517	.91285	.90530	.89702	.88788	.88079	.86227	.85387
40–44	.93478	.92729	.92110	.91357	.90341	.88755	.87783	.86747	.85472	.84570	.82183	.81097
45–49	.91592	.90625	.89887	.88882	.87577	.85540	.84294	.82938	.81318	.80162	.77194	.75811
50–54	.89109	.87857	.86933	.85638	.83959	.81336	.79735	.77904	.75986	.74506	.70938	.68143
55–59	.84396	.82619	.81551	.79742	.77403	.75128	.73015	.70333	.68953	.67056	.63295	.62035
60–64	.75411	.72655	.71269	.68505	.64950	.63355	.61630	.58968	.58552	.56080	.53373	.50645
65–69	.61797	.58995	.57062	.53017	.47846	.45872	.45088	.43696	.43145	.40897	.39133	.36391
70–74	.48335	.46161	.44485	.38274	.33258	.30876	.30089	.29024	.28298	.27175	.25076	.23109
75+	.30726	.29136	.28495	.26481	.21651	.19661	.18707	.17432	.16545	.15362	.13301	.11795

APPENDIX II (Continued)

SURVIVAL RATIOS OF MODEL LIFE TABLES (Stratum V)

FEMALES

Age in Years	EXPECTATION OF LIFE AT BIRTH											
	48.24	46.65	44.59	42.62	40.50	38.29	36.29	34.50	32.61	29.77	27.59	25.63
Births	.83975	.82911	.81321	.79740	.78167	.76083	.74014	.71960	.69919	.65881	.63882	.59926
0–4	.94650	.94295	.93761	.93226	.92688	.91970	.91245	.90516	.89781	.88286	.87530	.85982
5–9	.98539	.98449	.98318	.98187	.98057	.97888	.97718	.97552	.97385	.97059	.96898	.96577
10–14	.98334	.98231	.98083	.97935	.97787	.97595	.97395	.97212	.97025	.96656	.96473	.96112
15–19	.97704	.97564	.97360	.97155	.96953	.96688	.96432	.96165	.95907	.95399	.95148	.94653
20–24	.97148	.96975	.96721	.96466	.96215	.95886	.95557	.95236	.94915	.96233	.93974	.93359
25–29	.96473	.96257	.95942	.95626	.95313	.94907	.94498	.94096	.93698	.94924	.92528	.91760
30–34	.95811	.95555	.95178	.94802	.94428	.93945	.93458	.92978	.92504	.91568	.91106	.90189
35–39	.95205	.94937	.94477	.94047	.93328	.92846	.92272	.91924	.91412	.90338	.89808	.88758
40–44	.94389	.94045	.93538	.93036	.91948	.91446	.90759	.90530	.89959	.88706	.88089	.86866
45–49	.93073	.92616	.92021	.91409	.90166	.89327	.88472	.88131	.17623	.85846	.85073	.83548
50–54	.90934	.90375	.89563	.88756	.87208	.85926	.84927	.84480	.83820	.81650	.80653	.78684
55–59	.86910	.86014	.84888	.83740	.81795	.80198	.79516	.78914	.76635	.74386	.73015	.70315
60–64	.80353	.78809	.77219	.75531	.73246	.71409	.71076	.70243	.67458	.64684	.62802	.59093
65–69	.69426	.66708	.64447	.61931	.59524	.57668	.57221	.56074	.54291	.51484	.49014	.44176
70–74	.55912	.51823	.48672	.45103	.42269	.40176	.39577	.37890	.35586	.33496	.31153	.26214
75+	.33886	.31551	.29440	.26864	.24392	.22395	.21538	.20070	.17644	.16023	.14940	.12870

NOTES

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Graduation of Life Table Functions

S. Mitra

About a Few graduation Techniques

Application of mathematical models on mortality functions perhaps dates back to 1825 when Gompertz proposed a model suggesting a geometric progression of mortality with advance in age. His logic was that man's ability to resist his destruction decreases continually with increase in age and further his assumption of this pattern was that this decrease within a small interval of time is proportional to the level of that rate[1]. Makeham[2], working in 1860, modified Gompertz formula by adding a constant and later, Perks[3] in 1932, suggested another improvement by using a logistic approximation. It is well known that these models cannot adequately reproduce the life table functions at either extreme.

Recently, Hyrenius[4] has presented a life table technique for the working ages (15-80) that can be used to generate an integrated formula system for age-specific death rates, survivals and expectations of life on the basis of the assumption that the central mortality rate m_x can be expressed satisfactorily by means of a polynomial.

In fact however, the method described by Hyrenius is at most an alternative of the formula developed by Reed and Merrell[5] relating the central mortality rate with the probablity of dying. While Reed and Merrell's method was derived primarily from empirical investigations, their results were found to be an approximation of a more general relationship between m_x and q_x shown later by Greville[6]. Further, ti is not clear whether the method is presented by Hyrenius can produce better results than those obtained by using the Reed - Merrell method. The latter seems to have certain advantages from the computational point

of view besides the strong theoretical justification of the mathematical relationship between the two functions.

The derivation of life table functions from the central mortality rates has been considerably standardized and the computers can easily take care of the routine mathematical operations. What seems more important is the construction of an approximate version of a life table mortality statistics are either not available or are not accurate enough for the determination of central mortality rates. The United Nations[7] and later Coale[8] have made available a set of model life tables from which one can select the life table that corresponds with the infant mortality rate or the expectation of life at birth of the country in question. Because of proven regularities of the life table functions, an estimate of any of these two functions can be used to reproduce the entire life table with a reasonably high level of accuracy.

Method Based on Expectations of Life

The present investigation deals with a method of deriving life table functions that begins with the other end of a life table namely, the column showing the expectation of life. It has first been shown that the logarithm of the expectation of life e^o_x can be expressed as a polynomial in x and for ages 5 and over, a quadratic provides a reasonably good approximation for the same. Using the model life tables for empirical verifications, it has finally been shown that starting with an initial value of e^o_0, one may construct the entire set of e^o_x values and subsequently, the entire life table. Needless to say, that like model life tables, these tables will also represent the normative values and hence will be quite unique in nature. However, unlike the model tables, the parameters estimated in this series of tables are somewhat flexible and therefore, can be subjected to alterations, generating different life tables in the process. For the sake of continuity, some of these results shown earlier by Mitra[9] are summarized in the following.

Where l_x is the probability of surviving from age 0 to age x and $T_x = \int_x^{\alpha} l_x dx$, α being the upper age limit and

$e^o_x = T_x / l_x$, the derivative of e^o_x with respect to x, namely de^o_x / dx becomes equal to

$$(1 / l_x)\ dT_x / dx - (T_x / l_x^2)\ dl_x / dx.$$

Since $dT_x / dx = - l_x$ and the force of mortality $\mu_x = -/ 1 / l_x / dl_x / dx$, the above derivative can be written as

$$de^o_x / dx = e^o_x\ \mu_x - 1. \qquad (1)$$

It is known that the patterns of e^o_x and μ_x are opposite each other. The life expectancy increases from age 0, attains a maximum usually before age 5 and declines thereafter. μ_x, on the other hand declines from age 0, assumes a minimum value usually in the age interval 8 to 12 and increases thereafter. Both e^o_x and μ_x have one optimum and clearly from (1) the maximum value of e^o_x corresponds to some $x = \bar{x}$, at which $e^o_{\bar{x}} = 1 / \mu_{\bar{x}}$. (2)

From the inverse relationship between μ_x and e^o_x and also from (2), μ_x may be written as $\mu_x = 1 / e^o_x + \varphi' (x)$ (3)

where $\varphi' (x) = d\,\varphi (x)/ dx$ and $\varphi' (\bar{x}) = 0$

Equation (1) can therefore be rewritten as

$$de^o_x / dx = e^o_x\ \varphi' (x) \text{ or } \log_e e^o_x = \varphi (x) \qquad (4)$$

including in φ (x), the constant of integration.

Therefore, $e^o_x = e^{\varphi(x)}$. (5)

The model life tables prepared by the United Nations have been used to generate the values of $\bar{x}$ and $e^0_{\bar{x}}$ through free hand graduation of $1 / e^0_x$ and q_x (probability of dying at age x) in the age interval 0 to 5. The point of intersection $\bar{x}$ and the values of $e^0_{\bar{x}}$ and e^0_0 are shown in Table 1 covering a wide range of mortality patterns.

Table 1

MAXIMUM MALE LIFE EXPECTANCY $e^0_{\bar{x}}$ AT AGE $\bar{x}$ e^0_0 AND e^0_5 FOR A FEW MODEL LIFE TABLES

Model life table number	$\bar{x}$	$e^0_{\bar{x}}$	e^0_0	e^0_5
(1)	(2)	(3)	(4)	(5)
10	4.5	38.1	24.8	38.1
25	3.6	43.8	31.9	43.7
40	2.8	49.5	39.2	49.1
55	2.6	55.6	46.4	54.0
70	2.0	60.5	53.6	58.6
85	1.7	65.0	61.5	62.6
100	0.9	69.9	68.5	66.3

The sharp increase in life expectancy from age 0 to $\bar{x}$ is worth noting. So is the declining trend of $\bar{x}$ with increase in e^0_0. The decline of e^0_x after $e^0_{\bar{x}}$ is slow as revealed by the difference of $e^0_{\bar{x}}$ and e^0_5 which indicates that a graduation model for e^0_x using a few parameters is worthy of investigation. If such a formula can be found for say ages 5 and above, then that model together with e^0_0 and $e^0_{\bar{x}}$ will provide a reasonably complete picture of e^0_x. Obviously a graduation formula covering the entire age range will have to depend upon a larger number of parameters because the behavior of e^0_x at the childhood age shows a sharp reversal of the pattern.

Accordingly, for ages 5 and above, equation (4) has been assumed to have a Taylor expansion, i. e.

$$\log_e e^0 = a + bx + cx^2 + \ldots \qquad (6)$$

The assumptions seem to hold because the curves of e_x^o are continuous in the prescribed range and there seems to be no evidence that the derivatives do not exist. Further the second differences of $\log_e e_x^o$ based on model life tables are found to be quite small and can be regarded as constant for all practical purposes. Therefore a quadratic approximation, i. e.

$$\log_e e_x^o = a + bx + cx^2 \qquad (7)$$

should be satisfactory. The constants estimated by the method of least squares are shown in Table 2 where for the logarithms of e_x^o the base of 10 rather than e has been used.

Table 2

PARAMETERS OF THE QUADRATIC APPROXIMATION OF LOG e_x^o FOR A FEW MODEL LIFE TABLES FOR THE MALES

Mortality level (1)	a (2)	$b \times 10^2$ (3)	$c \times 10^3$ (4)
10	1.5984	−.433	−.102
25	1.6467	−.313	−.119
40	1.6922	−.251	−.127
55	1.7375	−.253	−.128
70	1.7644	−.194	−.134
85	1.7942	−.193	−.134
100	1.8233	−.223	−.130

The estimated values of c are sufficiently small as these were expected to be. The values are negative, show a slowly declining trend and a sign of increase at the end. b, which is also small and negative, appears to be an oscillating but diminishing function of the levels. The increasing trend, of a is however,

more regular Obviously, the estimates of these parameters, being dependent upon the model life tables, are subjected to the defects of those tables and hence should not be regarded as final. For a thorough analysis the parameters may be allowed to vary within tolerable limits and the results may be checked for consistancy by comparisons with other life table functions. So far as the model life tables are concerned, the life expectancies reproduced from the estimated parameters compare favourably with the actual values.

Derivation of Other Life Table Functions

It is apparent from the results presented earlier that an alternative method for constructing model life tables can be formulated if it can be shown that the information about e_x^0 is sufficient to generate other life table functions. Fortunately, T_x can be determined directly from e_x^0, when l_x can be obtained from $l_x = T_x / e_x^0$ and hence the entire life table can be completed. This is so because

$$\int_{x_1}^{x_2} dx / e_x^0 = \int_{x_1}^{x_2} l_x / T_x \, dx = \log_e (T_{x_1} / T_{x_2} \qquad (8)$$

Since $T_0 = l_0 e_x^0$ is known for a given model table, any T_x can be solved from (8) by putting $x_1 = 0$ and $x_2 = x$ provided the integral on the left hand side of (8) can be evaluated.

The values of e_x^0 can, however, be used to solve the above equation by numerical integration. It has been found that the approximation by trapezoidal rule even for five year intervals beyond age 5 is quite satisfactory. Thus for

$x_1 \geq 5$ and $x_2 - x_1 = 5$,

$$\log (T_{x_1} / T_{x_2}) = \tfrac{1}{2} (x_2 - x_1) (1 / e^0_{x_1} + 1 / e^0_{x_2} \qquad (9)$$

For the first age interval (0, 5), in which e_x^0 generally assumes its maximum value at $\bar{x}$, the recommended procedure is to use a quadratic approximation of $1 / e_x^0$ for each of the two subintervals (0, $\bar{x}$) and ($\bar{x}$, 5), with or even without any

Table 3

VALUES OF e_x^o COMPUTED FROM MODEL LIFE TABLE OF MALES COMPARED WITH THOSE OBTAINED BY FITTING A SECOND DEGREE CURVE TO LOG e^o.

Age	10		25		40		55		70		85		100	
x	M	G	M	G	M	G	M	G	M	G	M	G	M	G
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
0[1]	24.8	24.8	31.9	31.9	39.2	39.2	46.4	46.4	53.6	53.6	61.5	61.5	68.5	68.5
5	38.1	37.6	43.7	42.5	49.1	47.5	54.0	52.7	58.6	56.4	62.6	60.4	66.3	64.3
10	35.8	35.1	40.7	40.1	45.7	45.1	50.2	50.0	54.4	53.9	58.2	57.8	61.6	61.3
15	32.3	32.4	37.0	37.4	41.6	42.3	45.9	46.8	49.9	50.7	53.5	54.3	56.8	57.6
20	29.1	29.6	33.5	34.4	37.9	39.0	42.0	43.2	45.7	47.0	49.1	50.3	52.1	53.3
25	26.2	26.7	30.5	31.2	34.6	35.5	38.4	39.3	41.8	42.9	44.8	45.9	47.5	48.5
30	23.4	23.8	27.4	27.9	31.2	31.8	34.7	35.2	37.8	38.5	40.5	41.2	42.8	43.5
35	20.7	21.0	24.4	24.6	27.8	28.1	31.0	31.0	33.7	34.0	36.1	36.5	38.2	38.6
40	18.1	18.3	21.4	21.5	24.5	24.5	27.2	27.0	29.7	29.7	31.8	31.8	33.6	33.5
45	15.8	15.8	18.6	18.4	21.2	21.0	23.6	23.1	25.7	25.4	27.5	27.2	29.1	28.8
50	13.6	13.4	15.9	15.6	18.1	17.8	20.1	19.5	21.9	21.5	23.4	23.0	24.8	24.3
55	11.6	11.2	13.4	13.0	15.2	14.8	16.8	16.2	18.3	17.8	19.6	19.1	20.8	20.2
60	9.7	9.4	11.0	10.8	12.4	12.1	13.7	13.3	15.0	14.6	16.0	15.7	17.0	16.6
65	7.9	7.7	8.9	8.8	9.9	9.8	11.0	10.8	11.9	11.8	12.8	12.6	13.6	13.4
70	6.2	6.3	7.0	7.0	7.8	7 8	8.5	8.6	9.3	9.4	10.0	10 0	10.6	10.6
75	4.8	5.0	5.4	5.6	6.0	6.2	6.5	6.7	7.1	7.3	7.6	7 8	8.0	8.4
80	3.6	4.0	4.0	4.3	4.5	4.8	4.9	5.2	5.3	5.6	5.6	6.0	5.9	6.4

([1] Graduated e_0^o has been assumed to be the same as model e_0^o)

Note: M = Model, G = Graduated

Values of e_x^o corresponding to model number

correction for equalizing the derivatives at $\bar{x}$. In each of these two cases, the quadratic is assumed to produce a minimum value at $\bar{x}$, thereby reducing the number of parameters from three to two. The parameters can therefore be estimated from the given values of e_x^o at the two boundaries. Thus writing the quadratic

$$\text{as } 1 / e_x^o = m + nx + px^2 \tag{10}$$

and subjecting the equation to the condition that the minimum value is assumed at $\bar{x}$, the requirement for which is

$$n = -2p\bar{x} \tag{11}$$

the integral in (8) can be written as

$$\int_0^{\bar{x}} 1 / e_x^o \, dx = \int_0^x [m - px(2\bar{x} - x)] \, dx \tag{12}$$

for the interval 0 to $\bar{x}$. Since e_0^o and $e_{\bar{x}}^o$ are known, the parameters can be solved from (10) and (12) can be evaluated. The same procedure may be applied to the interval ($\bar{x}$, 5).

The equations (8) to (12) have been examined in some detail to verify the utility of this approach. For that, the model life table for males corresponding to level 70 ($e_0^o = 53.6$) has been selected and the results shown in Table 4. This table has a life expectancy (combined for the two sexes) of 55 years which seems to be quite close to the value of that index in India at the present time.

It may be pointed out that the life expectancies were computed by rounding off at the first decimal digit and accordingly there is no sense in carrying out the computations of l_x with a radix of 100,000. A radix of 1,000 has therefore been chosen for which the two sets of figures demonstrate considerable closeness. It seems certain that the figures would be a lot closer if the computations of life expectancies were carried out to a few more significant digits and the numerical integrations were based on intervals shorter than five years.

Table 4

GRADUATED VALUES OF l_x COMPARED WITH MODEL VALUES FOR MODEL LIFE TABLES LEVEL NUMBER 70 FOR MALES

Age x (1)	e^o_x (2)	1000 T_x Graduated (3)	1000 l_x Graduated (4)	1000 l_x Model (5)
0	53.6	53,565	1,000	1,000
1	58.8	52,644	895	882
5	56.4	49.186	872	840
10	53.9	44,920	833	828
15	50.7	40,821	805	819
20	47.0	36,844	784	806
25	42.9	32,958	768	787
30	38.5	29,138	757	767
35	34.0	25,370	746	748
40	29.7	21,668	730	726
45	25.4	18,052	711	699
50	21.5	14,564	677	665
55	17.8	11,624	633	620
60	14.6	8,249	564	561
65	11.8	5,624	477	484
70	9.4	3,488	371	387
75	7.3	1,898	260	274
80	5.6	862	154	162

Summary and Discussion

The model life tables prepared by the United Nations were based on a study that showed that the shape of the mortality curve is retained at all mortality levels and the infant mortality rate alone is generally sufficient for generating the entire mortality curve. The study reported here is based on the finding that the life expectancy can be regarded as an exponential function of age

and for all practical purpose the logarithm of the former can be approximated by quadratic equation of the latter variable namely, age for the entire range except the childhood interval of less than 5 years. This age interval (0-4) also includes the age at which expectation of life assumes its maximum value and that age approaches the age 0 with increase in life expectancy. The model life tables were used to determine this age, the maximum life expectancy and the parameters of the quadratic equation for a number of levels, and the results were quite encouraging. Finally, it has been shown that a set of life expectancies is theoretically sufficient to generate the entire life table. The conclusion can therefore be drawn that while the expectation of life at birth, from the point at view of its definition uses the entire information of the life table, it can also be manipulated, under certain empirical conditions, to release all the information that it used with virtually little or no loss in that process.

NOTES

1 Thus the force of mortality $\mu_x = Bc^x$

2 Makeham, W.M. "On the Law of Mortality and Construction of Annuity Tables", *Journal of the Institute of Actuaries* Vol 8, p. 301 [1860] Makeham wrote $\mu_p = A + Bc^x$ which by means of integration can also be writen as $l_x = ks^x g^{c^x}$

3 Perks, W. "Some Experiments in the Graduation of Mortality Statistics" *Journal of the Institute of Actuaries* Vol 63, p. 12 [1932] Perks modified the Makeham-Gompertz law by writing $\mu_x = [A + Bc^x] / [1 + Dc^x]$

4 Hyrenius, Hannes "Life Table Technique for the Working Ages" *Demography,* Vol. 7, p. 393. [1970] The assumption is $m_x = a_0 + a_1 x + a_2 x^2 + \ldots$

5 Reed, L, J. and Merrell, M. "A Short Method for Constructing an Abridged Life Table" *American Jourdal of Hygiene,* Vol. 30, p. 33 [1939] The formula for age interval of length n years, is ${}_nq_x = 1 - \exp(-n\,{}_nm_x - an^3\,{}_nm_x^2)$

6 Greville, T. N. E., "Some Methods of Constructing Abridged Life Tables" *The Record of the American Institute of Actuaries,* Vol. 32, p. 29 [1943]

7 United Nations, "Manuals on Methods of Estimating Population — Manual III, Methods for Population Projections by Sex and Age" ST/SOA/Series A, *Population Studies,* No. 25 [1956]

8 Coale, A. J. and Demeny, P. *Regional Model Life Tables and Stable Populations* Princeton University Press, Princeton, New Jersey [1966]

9 Mitra, S. "A Few properties of the Expectation of Life e_x^o" Presented at the Second World Population Conference in Belgrade [1965]

Mortality Projections for India upto 1985

*K. S. Gnanasekaran**

Mortality projections, besides its several uses in public health administration and planning, are foremost needed in preparing population projections for a country. About thirty years ago, the techniques of population projections involved extrapolating past trends using at best the logistic formula. Projections based on such mathematical methods attracted greater notice for their pitfalls and led to the development of the new approach to population projections based on the component method[1]. The use of this method enabled and consequently, led to further advances in regard to the techniques of projections of the two components of mortality and fertility. These methodological developments depended upon a long and reliable time series of vital statistics in addition to periodic population censuses.

For countries not having enough data, the component method is nevertheless adopted these days almost without exception for making population projections. This has given rise to undue confidence among the users, both in government and industries, in the quality of projections and as a sequel great disappointment when they are found off the mark by a later census. Therefore, side by side the use of component method, the quality of population projections must be greatly stressed at every stage of work. Improvements in the quality of projections can be largely achieved *firstly* by ensuring greater accuracy of projection inputs (i.e., base population data, mortality projections and fertility projections), and *secondly*, by evaluating more carefully the projection results to make sure whether they are internally consistent and in conformity with past trends, patterns and socio-economic changes[2].

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In this connection, the objectives of the present paper are twofold : 1) to examine the quality of mortality projections used in the previous official population projections for India, and 2) to suggest, in the light of above appraisal, new approaches that will improve a great deal the next and subsequent series of mortality projections and hence, the population projections for the country. Towards achieving the second objective, a series of mortality projections for India through 1985 is prepared here. It is, however, to be cautioned at the beginning itself that these projections are merely tentative for reasons that are pointed out in the following pages and need to be further refined on the basis of additional and/or new data that may become available in course of time and enable more detailed studies from the point of view of short and long term mortality projections.

Past Projections of Mortality : An Appraisal

An appraisal of mortality projections may be carried in respect of a) the bench-mark data or life table used and b) the technique followed to project mortality or more precisely, the survival ratios (P_x). Since 1951 census, several population projections had been made for India. Excepting Coale and Hoover's, the mortality projections underlying most of them rested on the census life tables. These life tables, inspite of the careful efforts by the actuaries to rectify the defective age-sex data of the censuses, are still exposed to serious weaknesses and criticisms. To cite Coale and Hoover, " the detailed shape of survivorship function really depends on how the life table constructor chose to smooth the raw age distributions that he dealt with. One result is that a comparison of successive Indian life tables reveals a very erratic behaviour in mortality by age. In short, the death rates at particular ages in the Indian life tables are as much determined by the way in which the original data were processed as by the real underlying mortality pattern in India "[3]. Therefore, Coale and Hoover constructed new life tables for use in their population projections for India[4].

To examine the official mortality projections, it may be noted that the projections adopted by the Expert Committees set up in 1958 and 1963, also depended on the census life table as the starting point for the projections. From the view point of projections,

beside its inherent weaknesses, the Indian census life tables reflect the mortality conditions of a decade, and hence may not be considered suited as the bench-mark for projections especially during the transition period. Life tables relating to a recent and short period, say, one year or an average of three or even five years may be preferred in order to ensure greater precision in the estimates.

The technique of mortality projection adopted by the Expert Committee depended heavily upon the U. N. Model Life Tables. It involved, in the first place, an assumption that the expectation of life at birth in future years would increase at the rate of say, 0.5 year per annum upto n (say 60) years at the end of projection period [5], and in the second place, selection if necessary, by linear interpolation the appropriate U. N. Model Life Table reflecting on expectancy in this case of n years. The P_x values for the intervening years were obtained on the basis of linear interpolation of the P_x values of the census life table and those of the assumed Model Life Table. An alternative approach is to assume the percentage decline in the P_x values for each age-sex category observed between two models (say, that between $e_0^0 = 35$ and $e_0^0 = 60$) and apply it to the P_x values for the base period obtained from the census life table.

Under this method of projection, it could happen that the pattern of mortality curve in the base year (i.e., census life table) may be different from the assumed model pattern for the end of projection period, and more often than not, the evolution of future mortality may not proceed along the path implied by this simple assumption in overall terms. Some specific rates in the base year could be even lower than the assumed rates of the terminal year, reflecting an increase in mortality for the concerned age group. This is an extreme situation; othertimes, it could happen that the rates of reduction under this method may not be consistent say between the two adjoining age groups or between the sexes. In short, the procedure so far adopted bears the risk of violating the "height-slope" relationship that had been observed before with regard to mortality decline in Europe, and is generally anticipated elsewhere including India[6]. Therefore, instead of resting heavily on model patterns, it is necessary in future to prepare mortality projections independently based on national statistics and knowdedge about socio-economic conditions and health development in the country

and its regions. The Model Life Tables should rather serve the purpose of evaluating the independent projections for its quality and/or any serious inconsistencies present in them.

Bench-mark Life Table for Present Projections

In India, recently, a new data scheme called the Sample Registration System was experimented on a pilot basis in 1964-1966 and has since been extended to all states and most of the Union Territories [7]. The SRS combines the continuous enumeration of events in the sample area with an independent survey at six months intervals. The simultaneous use of both enumeration and survey methods carries the advantage of detecting events missed by either of the two sources and provides an unduplicated count of the correct number of events. The results obtained from the SRS have been so far encouraging[8] and hold great potentialities for precise assessment of mortality situation in India.

For the purpose of mortality projection, a current life table[9] is of course ideal and recently, Vaidyanathan and this author. taking advantage of the SRS data, constructed a life table for India for 1968-1966[10]. This life table was founded on the age-sex specific death rates or ${}_{n}m_{x}$ values from the SRS for rural India in 1968 and 1969, and for urban India in 1969 that were combined by using a set of weights[11] to provide the all-India rates. The combined specific rates for all-India exhibited certain irregularities attributable largely to the misreporting of ages. Therefore, the rates were smoothed[12] before computing the current life table for India for 1968–1969 on the basis of the Coale-Demeny method[18].

This current life table for 1968–1969 given in Table 2, was adopted in this paper as the starting point of mortality projections. While this is a definite improvement over the earlier dependance on the census life table, it must be pointed that the exact level of infant and childhood mortality may still be subject to some error and calls for refinement on the basis of additional data and studies.

Trends in Mortality

It is now a well-known phenomenon that the death rate had declined more rapidly in the last two or three decades in almost all

high mortality societies. Based on statistics of the countries for which data are more accurate, this decline implied a gain in expectation of life at birth of atleast 0.5 year per annum. Table 1 presents the trends in expectation of life at birth in selected countries as they progressed from high to intermediate regime of mortality. Before the Second World War, the highest average annual increase in life expectancy was 0.4 years observed during 1920–1930 in the present developed countries. After 1945, the gain of 1.8 years in Ceylon was spectacular and far exceeded the pre-war average. In other countries, too, that experienced mortality transition during the past two decades, the annual increase in expectation of life at birth was estimated to be greater than one-half year per annum.

Mortality in India had also undoubtedly decreased steeply after 1951 as evident from the rapid increases of population in the 1961 and 1971 censuses. The exact magnitude of drop in mortality is, however, unknown and estimates vary considerably from one study to another. The uncertainty will continue to a large measure till the 1961—1970 census life table is published. Assuming that the previous two census life tables of 1941—1950 and 1951—1960 were subject to the same degree of error, the gain in expectation of life at birth may be seen to average about 0.9 year per annum in India. (Table 1)

Between 1956 (i.e., mid point of 1951–1960) and 1968–1969, the increase in expectation of life at birth, using the values of current life tables, amounted roughly 0.6 year for males and 0.7 year for females per annum. The unprecedented rise in life expectancy in recent years has been the result of great advances in the technology of disease control, international cooperation and of the high priority given to public health programmes by the national governments. As a result, though annual gains of the order of even more than one year in expectation of life at birth were reported for some countries, it must be noted that these are small countries compared to the size of India. Further, the socio-economic conditions of people and literacy levels of these countries are more favourable than those obtained in India, and hence, it is hypothesized here that such spectacular gains as witnessed in Ceylon or other relatively more advanced countries, cannot occur in all parts of India. For the purpose of projections, therefore, it is assumed in this paper that, the

Table 1

ACTUAL OR PROJECTED GAIN IN EXPECTATION OF LIFE AT BIRTH (e_0°) IN SELECTED COUNTRIES, 1900–1985

Country and Period	Expectation of life at birth (e_0°) in years		Average annual gain in e_0^0 since preceding period (years)	
	Males	Females	Males	Females
Ceylon				
1945–1947	46.8	44.7		
1952	57.6	55.5	1.8	1.8
1962	61.9	61.4	0.4	0.6
India				
1941–1950	32.5	31.7		
1951–1960	41.9	40.6	0.9	0,9
1961–1965[a]	48.7	47.4	0.9	0.9
1966–1970[a]	53.2	51.9	0.9	0.9
1971–1975[a]	57.3	56.0	0.8	0.8
1976–1980[a]	61.1	59.8	0.8	0.8
1981–1985[a]	63.1	61.8	0.4	0.4
Tailand				
1947–1948	48.7	51.9	...	...
1960	53.6	58.7	0.4	0.6
Egypt				
1965	45.5	48.3	...	...
1985[a]	57.0	60.5	0.6	0.6
European[b] Countries and USA				
1900	50.5		0.4	
1910	54.3		0.4	
1920	58.3		0.3	
1930	61.7		0.3	
1940	64.6		0.3	

a Projected values.

b The countries include Denmark, England and Wales, France, Netherlands, Norway, Sweeden and the USA (Massachusetts state only).

Sources: United Nations, *Demographic Year Book*, 1966, pp. 572–574; India, Office of the Registrar General, *Report on the Population Projections*, p. 29; Cairo Demographic Centre, *Demographic Meosures and Population Growth in Arab Countries*, 1970, p. 274; and United Nations *Population Bulletin* No. 6, 1962, pp. 40 and 49.

future improvements in mortality will be moderate and that, the overall gain in the expectation of life at birth will be about 0.6 year per annum till it reaches the mark of 60 years. The increase thereafter is anticipated to slow down depending upon the substantial progress in the living condition of the people.

Projection Technique and Results

The method of translating the assumptions regarding future mortality trends was emphasized earlier as an important factor in enhancing the quality of projections. In this connection, the technique followed in the official projections was considered unsatisfactory by the present author. This paper, too, lacking a time series of accurate mortality statistics or current life tables, resorts to model life tables (Coale-Demeny West) but; differs regarding the procedure followed so as to improve the projections.

According to the present method, the West model levels (see Table 2) by age groups and sex of the current life table for India 1968—1969 were raised by one to obtain the mortality levels for each age sex group for 1972—1973. One level for every four years was adopted to project the assumption made earlier of an increase of 0.6 year in expectation of life at birth per annum or about 2·5 years in four years. The procedure was repeated to create the life tables for 1976—77, 1980—81 and 1984—1985. Thus, the projected life table for 1984—1985 will show an addition of four to the initial levels for 1968—1969.

From the standpoint of preparing population projections, the survival ratios are only required. Therefore. the q_x values corresponding to the projected levels for 1972—1973, 1976—1977, 1980—1981 and 1984—1985 were read off from the Coale, Demeny West model life tables and then the life tables were calculated by following again the Coale-Demeny method. From these life tables by sex, the survival ratios for different periods were derived using the standard formula, i. e., $P_x = {}_nL_x + 5/{}_nL_x$. These values and other important life table fuctions are given in Tables 3 to 6 and Figure 1.

Table 2

CURRENT LIFE TABLE BY FIVE-YEAR AGE GROUPS AND SEX, INDIA
1968–1969

Age Group (Years)	MALES						FEMALES					
	Level	1000_{q_x}	1000_{m_x}	l_x	P_x	$\overset{\circ}{e}_x$	Level	1000_{q_x}	1000_{m_x}	l_x	P_x	$\overset{\circ}{e}_x$
0	13	139.42	153.79	100000	.83749[a]	50.4	12	131.71	144.04	100000	.83964[a]	49.9
1–4	13	70.84	18.58	86058	.94494[b]	57.5	12	82.64	21.85	86829	.93720[b]	56.5
5–9	13	20.59	4.16	79961	.98382	57.8	12	24.17	4.89	79654	.97958	57.4
10–14	15	11.68	2.35	78315	.98727	53.9	13	16.59	3.34	77729	.98166	53.8
15–19	17	13.78	2.78	77400	.98468	49.5	14	20.12	4.06	76440	.97691	49.7
20–24	18	16.87	3.40	76333	.98262	45.2	14	26.12	5.29	74902	.97213	45.6
25–29	18	17.90	3.61	75045	.98089	40.9	14	29.66	6.02	72946	.96846	41.8
30–34	18	20.34	4.11	73702	.97542	36.6	14	33.47	6.81	70782	.96452	38.0
35–39	17	28.90	5.87	72203	.96688	32.3	14	37.56	7.66	68413	.96011	34.2
40–44	17	37.47	7.64	70116	.95130	28.2	14	42.32	8.65	65842	.95600	30.4
45–49	15	60.38	12.45	67489	.92904	24.2	15	45.75	9.36	63057	.94636	26.7
50–54	15	82.22	17.15	63414	.90832	20.6	15	61.90	12.78	60172	.92742	22.8
55–59	15	111.97	21.49	58200	.87082	17.3	15	83.96	17.53	56447	.90025	19.2
60–64	15	159.47	34.66	52265	.81116	13.9	16	116.99	24.85	51708	.85715	15.7
65–69	15	223.76	50.39	43930	.73551	11.1	16	172.15	37.67	45659	.78746	12.5
70–74	15	316.95	75.33	34100	.63146	8.6	16	261.33	63.89	37799	.68656	9.5
75–79	15	444.04	114.16	23292	.39320[c]	6.4	16	383.99	95.04	27921	.42260[c]	7.0
80+	15	1000.00	220.75	12949	—	4.5	16	1000.00	208.33	17200	—	4.8

[a] P (Birth), [b] P (0–4), [c] T (80)/T(75)

Source: K. E. Vaidyanathan and K. S. Gnanasekaran, "A Current Life Table for India, 1968–1969," Paper submitted to the *Second Asian Population Conference*, Tokyo, 1972.

Table 3

PROJECTED LIFE TABLE BY FIVE-YEAR AGE GROUPS AND SEX, INDIA
1972-1973

Age Group	MALES					FEMALES				
	1000_{qx}	1000_{mx}	1_x	P_x	e^o_x	1000_{q_x}	1000_{m_x}	1_x	P_x	e^o_x
0	124.53	135.87	100000	.85583[a]	52.8	118.31	128.17	100000	.85661[a]	52.5
1–4	60.07	15.64	87547	.95280[b]	59.3	71.69	18.81	88169	.94528[b]	58.5
5–9	18.07	3.65	82287	.98582	59.0	21.36	4.32	81848	.98219	59.0
10–14	10.22	2.06	80800	.98892	55.0	14.20	2.86	80100	.98422	55.2
15–19	11.94	2.40	79974	.98686	50.6	17.39	3.51	78963	.97998	51.0
20–24	14.34	2.89	79019	.98530	46.1	22.69	4.59	77590	.97571	46.8
25–29	15.06	3.03	78077	.98394	41.8	25.91	5.25	75829	.97236	42.8
30–34	17.06	3.44	77114	.97903	37.4	29.41	5.97	73864	.96864	38.9
35–39	24.93	5.05	76040	.97116	33.0	33.37	6.79	71692	.96426	35.0
40–44	32.84	6.68	74144	.95614	28.8	38.19	7.79	69300	.96004	31.1
45–49	55.24	11.36	71709	.93452	24.6	41.80	8.54	66653	.95071	27.3
50–54	76.33	15.87	67748	.90956	20.9	57.11	11.76	63867	.93259	23.4
55–59	105.71	22.32	62577	.87248	17.5	78.34	16.31	60220	.90680	19.6
60–64	151.91	32.88	55962	.81902	14.2	109.32	23.13	55502	.86524	16.1
65–69	215.27	48.25	47461	.74417	11.3	163.33	35.57	49435	.79682	12.7
70–74	307.51	72.68	37244	.64085	8.8	250.82	57.36	41361	.69691	9.7
75–80	433.73	110.76	25791	.40104	6.5	372.85	91.66	30987	.43233	7.2
80+	1000.00	215.98	14605	—	4.6	1000.00	202.43	19433	—	4.9

[a] P (Birth), [b] P (0–4), [c] T(80)/T(75)

Source: Based on Table 2. See text for method of projection.

Table 4

PROJECTED LIFE TABLE BY FIVE-YEAR AGE GROUPS AND SEX, INDIA
1976–1977

Age Group (Years)	MALES					FEMALES				
	1000_{q_x}	1000_{m_x}	l_x	P_x	$\overset{o}{e}_x$	1000_{q_x}	1000_{m_x}	l_x	P_x	$\overset{o}{e}_x$
0	111.36	120.34	100000	.87196[a]	55.2	105.48	113.25	100000	.87369[a]	55.3
1	51.05	13.21	88864	.95941[b]	61.1	59.76	15.6	89452	.95381[b]	60.8
5	15.89	3.20	84327	.98763	60.3	18.39	3.71	84106	.98468	60.5
10	8.81	1.77	82987	.99052	56.2	12.18	2.45	82559	.98649	56,6
15	10.17	2.05	82257	.98895	51.7	14.85	2.99	81553	.98285	52.3
20	11.92	2.40	81420	.98787	47.2	19.49	3.94	80342	.97908	48.0
25	12.34	2.48	80449	.98687	42.8	22.37	5.09	78776	.97606	43.9
30	13.93	2.81	79456	.98250	38.3	25.56	5.18	77014	.97258	39.9
35	21.11	4.27	78349	.97531	33.8	29.34	5.96	75046	.96829	35.9
40	28.35	5.75	76695	.96092	29.4	34.16	6.95	72844	.96401	31.9
45	50.13	10.28	74521	.93998	25.2	37.89	7.73	70356	.95502	27.9
50	70.42	14.60	70785	.91562	21.4	52.34	10.75	67690	.93776	23.9
55	99.38	20.91	65800	.87938	17.9	72.70	15.09	64147	.91338	20.1
60	144.21	31.08	59261	.82703	14.6	101.64	21.42	59484	.87338	16.5
65	206.59	46.08	50715	.75306	11.6	154.43	33.5	53438	.80630	13.1
70	297.81	69.98	40238	.65050	8.9	240.15	54.58	45186	.70747	10.0
75	423.10	107.33	28255	.40976[c]	6.7	361.46	88.24	34335	.44265[c]	7.3
80	1000.00	210.79	16300	—	4.7	1000.00	196.27	21924	—	5.1

[a] P (Birth), [b] P (0–4), [c] T (80)/T(75)

Source: As in Table 3.

Table 5

PROJECTED LIFE TABLE BY FIVE-YEAR AGE GROUP AND SEX, INDIA 1980–1981

Age Group (Years)	MALES					FEMALES				
	$1000q_x$	$1000m_x$	l_x	P_x	$\mathring{e}_x$	$1000q_x$	$1000m_x$	l_x	P_x	$\mathring{e}_x$
0	98.57	105.59	100000	.88750[a]	57.6	93.39	99.62	100000	.88895[a]	57.9
1	42.70	10.99	90143	.96562[b]	62.9	50.01	12.93	90661	.96125[b]	62.9
5	13.79	2.78	86293	.98935	61.6	15.73	3.17	86127	.98697	62.1
10	7.46	1.50	85103	.99204	57.5	10.29	2.07	84772	.98862	58.0
15	8.46	1.70	84468	.99098	52.9	12.48	2.51	83900	.98552	53.6
20	9.57	1.92	83753	.99032	48.3	16.50	3.33	82853	.98223	49.3
25	9.78	1.96	82951	.98958	43.8	19.06	3.85	81486	.97953	45.1
30	11.07	2.80	82140	.98576	39.2	21.90	4.43	79933	.97633	40.9
35	17.45	3.52	81231	.97929	34.6	25.47	5.16	78182	.97218	36.7
40	24.03	4.86	79814	.96556	30.1	30.24	6.14	76191	.96788	32.6
45	45.10	9.22	77896	.94540	25.8	34.05	6.93	73887	.95928	28.6
50	64.54	13.34	74383	.92170	21.9	47.62	9.76	71371	.94288	24.5
55	93.01	19.51	69582	.88634	18.3	67.08	13.88	67972	.91993	20.6
60	136.43	29.28	63110	.83515	14.9	93.99	19.06	63412	.88152	16.9
65	197.77	43.89	54500	.76211	11.8	145.51	31.39	57452	.81584	13.4
70	287.91	67.08	43722	.66039	9.1	229.39	51.82	49092	.71816	10.2
75	412.21	103.85	31134	.41889[c]	6.8	349.91	84.82	37831	.45333[c]	7.5
80	1000.00	205.42	18300	—	4.9	1000.00	190.04	24594	—	5.3

[a] P (Birth), [b] P (0–4), [c] T (80)/T(75)

Source: As in Table 3.

Table 6

PROJECTED LIFE TABLE BY FIVE-YEAR AGE GROUPS AND SEX, INDIA
1984–1985

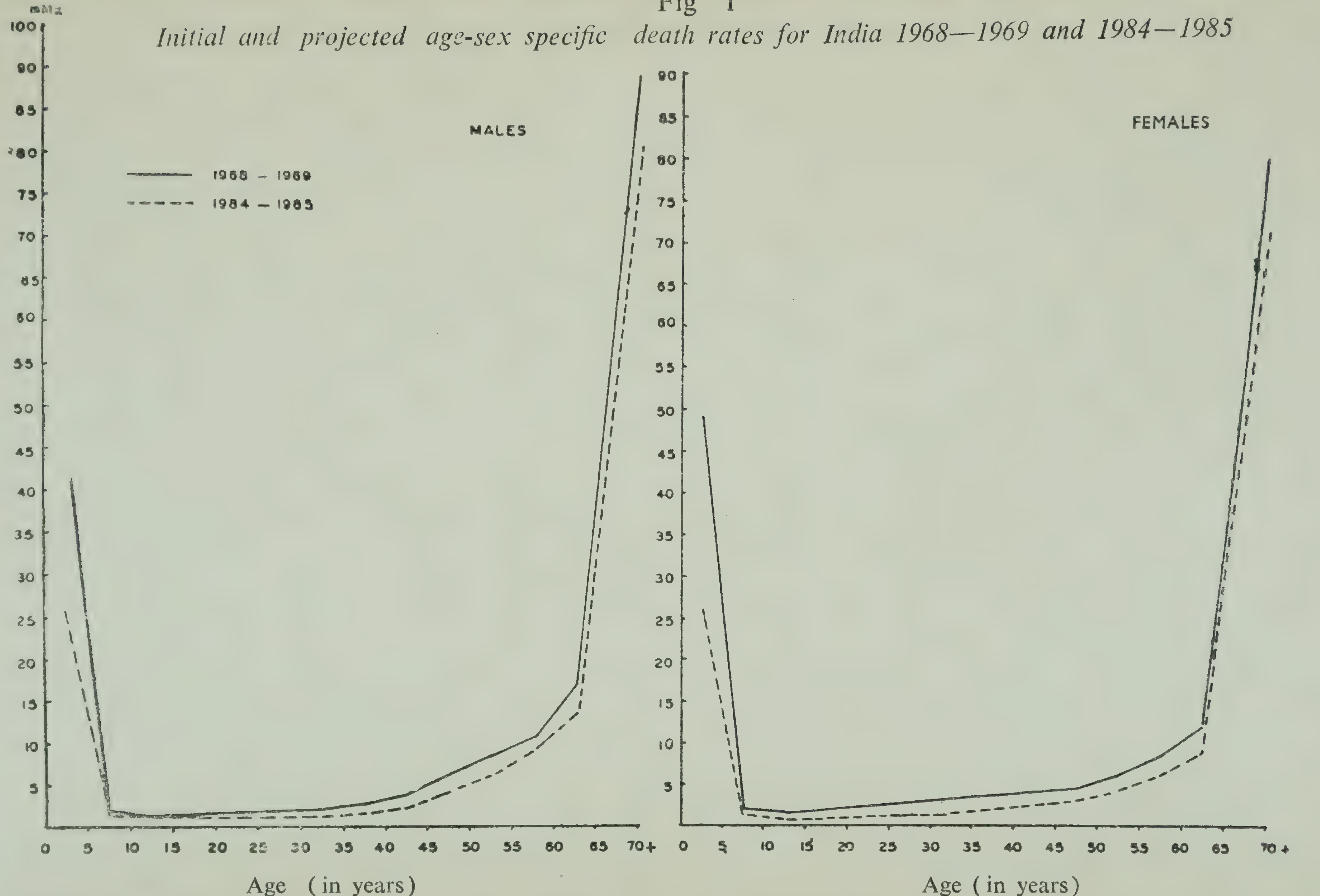
Age Group [Years]	MALES					FEMALES				
	$1000q_x$	$1000m_x$	l_x	P_x	$\overset{o}{e}_x$	$1000q_x$	$1000m_x$	l_x	P_x	$\overset{o}{e}_x$
0	86.21	91.83	100000	.90214[a]	60.1	81.77	86.77	100000	.90332[a]	60.6
1	34.96	8.94	91379	.97174[b]	64.7	41.18	10.58	91823	.96818[b]	64.9
5	11.79	2.37	88184	.99101	63.0	13.26	2.67	88041	.98909	63.7
10	6.16	1.24	87145	.99350	58.7	8.54	1.72	86874	.99060	59.5
15	6.83	1.37	86608	.99294	54.1	10.26	2.06	86132	.98803	55.0
20	7.29	1.46	86016	.99270	49.4	13.70	2.76	85248	.98519	50.5
25	7.33	1.47	85389	.99221	44.8	15.94	3.21	84080	.98281	46.2
30	8.28	1.66	84765	.98882	40.1	18.45	3.72	82740	.97990	41.9
35	14.08	2.84	84063	.98292	35.4	21.78	4.40	81213	.97592	37.6
40	20.12	4.07	82879	.96996	30.9	26.43	5.36	79444	.97166	33.4
45	40.16	8.20	81211	.95076	26.5	30.29	6.15	77344	.96346	29.3
50	58.71	12.10	77950	.92774	22.5	42.97	8.78	75001	.94796	25.1
55	86.65	18.11	73374	.89331	18.7	61.51	12.69	71778	.92641	21.1
60	128.63	27.49	67016	.84332	15.2	86.45	18.07	67363	.88958	17.3
65	188.87	41.71	58396	.77127	12.1	136.64	29.33	61539	.82537	13.7
70	277.87	64.54	47367	.67045	9.4	218.63	49.09	53130	.72889	10.5
75	401.12	100.35	34205	.42853[c]	7.0	338.27	81.43	41514	.46434[c]	7.8
80	1000.00	199.80	20485	—	5.0	1000.00	183.76	27471	—	5.4

[a] P (Birth), [b] P (0-4), [c] T (80)/T(75)

Source: As in Table 3.

Fig 1

Initial and projected age-sex specific death rates for India 1968—1969 and 1984—1985



Source: Based on Tables 2 & 6

According to the present projections, the expectation of life at birth in 1984—1985 will be about 60.1 years for males and 60.6 for females or an addition of 9.7 and 10.7 years respectively in 16 years (see Table 7.) This assumption implylng an annual gain of 0.6 year may be considered rather conservative by other demographers or it may be necessary especially for short term population projections to include alternative assumptions. As an alternative variant Table 3, 4, 5 and 6 can be assumed for the periods 1971—1972, 1974—1975, 1977—1978 and 1980—1981 respectively reflecting an increase in the expectation of life at birth of 0.8 year per annum. The P_x values for the intervening years can be obtained by linear interpolation.

Table 7

PROJECTED EXPECTATION OF LIFE AT BIRTH BY SEX FOR INDIA 1968—1969 to 1984—1985

Period	Expectation of life at birth [in years]	Increase since preceding period [in years]	Expectation of life at birth [in years]	Increase since preceding period [in years]
	MALES		FEMALES	
1968—1969	54.4	. .	49.9	. .
1972—1973	52.8	2.4	52.5	2.4
1976—1977	55.2	2.4	55.3	2.8
1980—1981	57.6	2.4	57.9	2.6
1984—1985	60.1	2.5	60.6	2.7

Source: Based on Tables 2 and 3 to 6.

Concluding Remarks

The main objective of this paper is to stress the need for improvement of mortality projections underlying the official population projections for India. Towards this goal, a new approach was made here to prepare tentative mortality projections for India through 1985. This approach differed from the earlier ones in respect of a) the bench-mark life table (i. e., a current life table instead of the census life table) used for projections and b) the technique of projections. More refinements in both these directions are essential over the coming years.

To concentrate here on the improvement of technique of projections, two interrelated aspects must be paid great attention. The first relates to the assumptions regarding future mortality trends, and the second concerns the technique of translation of different assumptions into life table functions in particular the survival ratios or P_x values. In this paper, the mortality assumption was made in terms of annual gain in the overall expectation of life at birth and for translating it into survival ratios, resort was made to the Coale-Demeny West model life tables.

Although the adopted techniqe manifests certain advantages over the previous methods, it is not very satisfactory except perhaps in the immediate short period. For, as pointed before, this author believes that the mortality pattern and therefore, the speed of decline of specific mortality rates may differ in individual countries from that embodied in the model life tables. There fore, as a time series of reliable mortality data becomes available sequel to the development of the SRS and the improvements under way in the vital statistics system, the trends in specifiic mortality rates of the country must be carefully and continuously studied and the results be made use of to project each specific rate or segments of mortality curve.

It may also be useful to examine the differentials by regions or rural urban sectors, and to borrow the actual experience of mortality evolution in the advanced areas or among the leaders in mortality control to project the future trend for the country as a whole. Further insight into mortality reduction can be obtained by collecting and analysing mortality statistics by causes of death.

NOTES

1 For a pioneering attempt of this method, see P. K. Whelpton, et al., *Forecasts of the population of the United States*, 1945–1975, U. S. Government Printing Office, Washington, D. C. 1947.

2 For methods of evaluation of projection results, see K. S. Gnanasekaran, "Some Tests for Evaluating Population Projections", Paper submitted to the Indian Census Centeuary Seminar, New Delhi, October, 1972.

3 Coale A. J and E. M. Hoovar, *Population Growth and Economic Development in Low Income Countries*, Princeton, Princeton University Press, 1958, p. 346.

4 For details of methodology employed by these authors to construct life table, Ibid, pp. 346–351.

5 The offieial projections assumed an annual increase in the expectation of life at birth (e_0^0) of 0.9 year npto 1970, 0.75 during 1971–1975 and 0.6 year during 1976–1980. See Office of the Registrar General, *Report on the Population Projections*, New Delhi, Government of India Press 1969, p. 7.

6 The "height slope" phenomenon is described in detail in F. W. Notestein, et al., *The Future Population of Europe and the Soviet Union*, Geneva, League of Nations, 1944.

7 For a detailed account of SRS, see Office of the Registrar General, Vital Statistics Division, *Sample Registration of Births and Deaths in India (Rural) 1965–1968*, New Delhi.

8 For evaluation of the SRS, see B. L. Agarwal, "Sample Registration in India", *Population Studies*, Vol 23 No. 3, Nov. 1969, pp. 379–394. Also H. B. Wells and B. L. Agarwal "Sample Registration in India", *Demography*, Vol. 4, No. 1, pp. 374–387

9 The term "current life table" is here used specially to denote a life table calculated on the basis of a direct method using death statistics.

10 See K. E. Vaidyanathan and K. S. Gnanasekaran, "A Current Life Table for India, 1968–1969" Paper submitted to the Second Asian Population Conference, Tokyo, November, 1–3, 1972.

11 The weights used for 1968 rural, 1969 rural and 1969 urban rates were 0.4, 0.4, and 0.2 respectively Ibid., p. 8.

12 For details about the procedure of smoothing, Ibid., pp. 7–12.

13 The method is described in A. J. Coale and P. Demeny *Regional Model Life Tables and Stable Populations*, Princeton, Princeton University Press, 1966, p. 20.

A Hypothetical Indian Population Projection *

G. E. Immerwahr

This paper serves to illustrate the virtual inevitability of large population growth in India in the decades to come. It shows how, even if age-specific fertility rates were to be suddenly and drastically reduced to such an extent that the " intrinsic rate "[1] of population growth immediately becomes zero, India's population would still grow for several decades and reach a level alomst 50 per cent greater than its present size.

If a population closed to migration has (1) an age-sex-specific mortality schedule that remains constent from year to yeart (2) an age-specific fertility schedule that similarly remains constant and (3) a sex-ratio-at-birth that also remains constant, then this population may be said to have "stable population conditions ". This does not necessarily mean that the population is already fully stablized-i.e., that it already has a constant rate of increase over each unit of time and an unchanging age-and-sex distribution for generally it could have these only if the same stable population conditions had already existed for a long period in the past. It does mean, however, that regardless of its present age-and-sex distribution, it will ultimately reach a constant rate of increase and an unchanging age-and-sex distribution, provided these schedules and the sex-ratio-at-birth continue without change. The ultimate rate of increase and the age-and-sex distributions are functions of the schedules and the sex-ratio of births and not of the size or distribution of the present population[2].

A stationary population is a special case of a fully stabillized population, and "stationary population conditions" are a special

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case of stable population conditions. The requisite for stable population conditions to be stationary population conditions is this : the fertility schedule (together with the sex-ratio-at-birth) must be such that when they are applied to the L_x values of the life table formed by the female mortality rates, they will produce an annual number of female births equal to l_o of that life table. In this application, L_x values for ages beyond the reproductive years may be ignored.

Just as stable population conditions may take many years to produce a fully stabilized population, so stationary population conditions may take many years to produce an actually stationary population.

Computer Projection

In connection with our computer simulation project, we have developed a family of life tables for India, one for each of the years 1951 through 1981. See Appendix. We have also made population projections on the computer in five-year intervals, using five-year survival ratios derived from these life tables. For the purpose of this computer projection we have used the 1953 life table to represent the mortality in each year during 1951-55, the 1958 table to represent mortality in each year during 1956-60, etc. Similarly we have used fertility in five-year intervals in the projection, and we have assumed that 51.3 per cent of all children born are males, 48.7 per cent females.

In our projection, starting with the 1961 Indian census figure of 439.2 million, and ignoring migration, we have arrived at a population of 559.5 million at the beginning of 1971. Our population projection model can accept migration input, but for this purpose all migration after 1961 has been assumed to be zero.

For this computer projection we have assumed that, beginning with 1971, the 1971 life tables would apply for the indefinite future without any further decline in mortality. These 1971 life tables, as we have calculated them, involve expectations of life at birth of 50.6 years for males and 51.2 for females. We chose the following age-specific fertility rates which result, when used in combination with the 1971 life table for females, in stationary population conditions, and therefore resulted in the value $r = 0$, where r is the intrinsic rate of natural increase:

Table 1

Ages	Annual age-specific fertility rate
10–14	.001
15–19	.070
20–24	.158
25–29	.140
30–34	.103
35–39	.060
40–44	.014
45–49	.0

These fertility rates correspond to total fertility of 2.730 which is 48 per cent of the mean total fertility assumed for 1966-70 and therefore represents that the birth rates will suddenly be cut approximately in half.

Starting with this 1971 population, and with a continuation of this 1971 life table and the above fertility rates and a proportion of 48.7 per cent girls at birth, we arrive at the following results (population figures in millions):

Table 2

Period	Mean crude rates (per 1000) in period			Population end of period (millions)
	Birth	Death	Increase	
1966–71	41.2	16.6	24.6	559
1971–76	20.9	12.8	8.1	583
1976–81	22.9	13.1	9.8	612
1981–86	25.1	14.0	11.1	647
1986–91	25.9	14.6	11.3	684
1991–96	24.3	14.9	9.4	717
1996–01	21.9	15.0	6.9	742
2001–06	20.6	15.4	5.2	762
2006–11	20.2	16.0	4.2	778
2011–16	20.4	16.8	3.6	792
2016–21	20.4	17.5	2.9	804
2021–26	20.1	18.2	1.9	811
2026–31	19.6	18.8	0.8	815
2031–36	19.4	19.3	0.1	815
2036–41	19.5	19.6	−0.1	815
2041–46	19.7	19.8	0.1	814
2046–51	19.8	19.8	0	814
2051–56	19.7	19.7	0	814
2056–61	19.6	19.4	0.2	815
2061–66	19.6	19.5	0.1	815
2066–71	19.6	19.6	0	815

The period 1966–71 represents the 60 months [five years] ending with the census date 28 February 1971, and each subsequent period is a corresponding 60-month period [e. g., March 1971 – February 1976].

It can be said that *in total number* the population becomes virtually stationary in 2031 at the level of about 815 million. This means a 60-year period would be required for a virtually constant total population to be attained, with a population increase of 46 per cent during this period despite a zero intrinsic growth rate throughout the period.

Not until the end of about a century, however, would the age composition of the population be close to stationary stable conditions (which in operations research would be called "steady state" conditions), as may be seen from the following table:

Table 3

Year	Percentage distribution by ages [both sexes combined] 0–14	15–34	35–59	60+	Total	Number of women 15–44 [millions]
1971	42.2%	32.1%	20.3%	5.4%	100.0%	114
2001	28.1	32.2	31.4	8.3	100.0	174
2031	24.8	29.6	29.7	15.9	100.0	173
2071	24.4	30.1	31.1	14.4	100.0	171

The "steady state" percentage for the four age groups, bashd on the life tables, should respectively be 24.25%, 30.1%, 31.0% and 14.4%.

Discussion

The results of this projection, including not only the growth of population but the changes in crude birth and death rates and in population age composition, may at first glance seem almost unbelievable. This is particularly true of the short-range results, and it is of interest to examine some of these.

The first question that may be asked is, why does the crude death rate fall so rapidly in the first five years following 1971? This is because a large proportion of deaths in today's population are among recently born children, and when births are reduced the immediate effect is to reduce deaths. The computer projection shows that of the 108.5 million children born during 1966-71, 16.6 million died during that same period; this was 38.1 per cent of the total of 43 7 million deaths (of all ages) in the period [13]. During the period 1971-76 only 59.7 million children are born, and only 8.2 million of them die during the period. The total deaths (of all ages) in the period is 36.5 million.

The next question is, why does the crude birth rate rise for several five-year periods following 1976? It has been noted that in many developing country populations with high fertility rates the crude birth rate may fall even when age - specific fertility remains the same. This is because the proportion of children 0-14 in the population is growing and the proportion of women in the reproductive ages is correspondingly falling. Here just the reverse is true in the short - range; the proportion 0-14 is falling and the proportion in the reproductive ages is rising.

Ultimately, of course, both crude birth rates and death rates converge toward the intrinsic rates for a population with these particular mortality and fertility schedules, such intrinsic rates being 19.6 per 1000 in each case. Over the long run crude death rates rise because the population becomes older and crude birth rates fall for the same reason. But neither movement is monotonic. In the decades of the 2030's and 2040's the number and proportion of elderly persons (those who were born just before 1971) will be temporarily very high (see also Table 3) so that crude birth rates in the 2030's will be slightly below the intrinsic and crude death rates in the 2040's slightly above the intrinsic.

Perhaps the continuing increase in the population following 1971, as shown in Table 2, can best be explained by the fact that the large numbers of children already born before 1971 will become and remain parents for several decades to follow and will produce large numbers of new children even if fertility rates drop. As shown in Table 3, the number of women at ages 15-44 may be expected to increase by at least one-half over the next three decades.

Another question that may be asked is how far fertility rates must fall if any future population growth is to be prevented. This I have worked out for the period 1971-76 and I find that the age-specific fertility rates shown in Table 1, which are only about one-half the estimated mean fertility rates of 1966-71 period, would themselves need to be cut almost in half again (actually be reduced by 45 per cent). These further reduced rates correspond to a total fertility of only 1.50 (well below a two-child family norm). With these rates the total births and total deaths during 1971-76 would each be 32.8 million, the population would remain at 559.5 million and the annual crude birth and death rates would each be 11.7 per

thousand. During subsequent 5-year periods, the fertility rates could gradually rise without causing a population increase since crude death rates would rise with the gradual aging of the population.

It should be clear that bringing down the number of births merely to the currently prevailing annual number of deaths will not achieve immediately a stationary population. Since the reduction in births will of itself reduce deaths, the number of births would have to be brought down to a level well below the current level of deaths.

This entire exercise has admittedly been a highly hypothetical one, yet the main projection results (namely, a large population increase even with immediate drastic fertility reduction) serve to point up the urgency of the Indian population problem.

It should be noted not only that the population growh shown in Table 2 is far underestimated because the fertility reduction assumed as immediate is not actually likely to take place for many years, but may be further understated because further future declines in mortality have been ignored. During the 1960's it has been reasonable to believe that mortality declines have produced a greater decrease in the crude death rate than has taken place in the crude birth rate. Further mortality declines in the future are almost a certainty, unless population growth is at so great a rate as to result in significant increases in disease, food shortages, pollution of the environment or social tension.

APPENDIX

Indian Life Tables Developed for Computer Simulation Project

For the project it was desired to develop a family of tables which would give q_x values for age x and each sex for every one of the years 1951-81. It was also desirable that the tables be derived in such a manner that the computer could readily select q_x values for the appropriate year for which experience would be simulated.

For this purpose the first step was to construct tables for the year 1956. This was done based upon smoothed 1961 census data and upon a re-smoothing of the 1951 data, so that the tables differed appreciably from the 1951-60 official Indian life tables. For the year 1981 it was assumed that the Coale-Demeny West table 17 would apply for males and table 16 for females. For each sex and age separately individual ratios were obtained of the q_x values for separate years on the theory that q_x values decreased in geometric progression from one year to the next. Thus given q_{xm}^{1956} and q_{xm}^{1981} for males age x, a value Z_{xm} was found $= (q_{xm}^{1981} / q_{xm}^{1956})^{1/25}$. Then for any year of $(1951 \leq y \leq 1981)$, the value q_{xm}^{y} for that year was found as $q_{xm}^{1956} Z^{y-1956}$

The expectations of life at birth for some of the tables were as follows:

Table for year	*Male*	*Female*
1951	34.52	33-90
1953	36.34	35.78
1956	38.99	38.57
1958	40.69	40.38
1963	44.74	44.77
1968	48 48	48.90
1971	50.58	51.24
1973	51.92	52.75
1978	55.06	56.31
1981	56.81*	58.31*

* Not exactly equal to the Coale-Demeny values because of modifications introduced at older ages and because of being based on single year L_x values.

NOTES

[1] Intrinsic rate is an eventual long term rate. For a more exact description see G. W. Barclay, *Techniques of Population Analysis*, New York, John Wiley.

[2] The one exception to this rule is the case where a present population has no females in the reproductive ages. Such a population would ulitmately vanish.

[3] The 16.6 million deaths were not the only deaths under age 5, since approximately two million children born during 1961–66 also died during 1966–71 but before reaching age 5. At present about 43 per cent of total deaths in India are apparently of children under age 5.

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